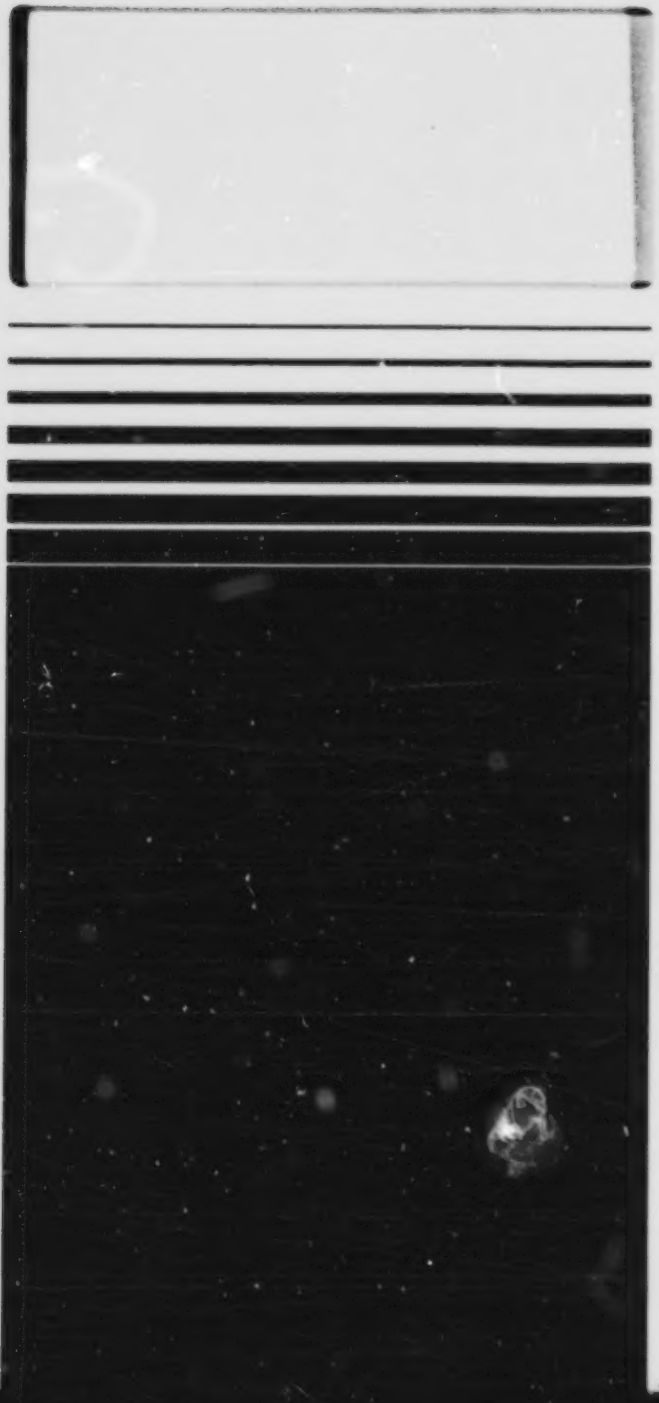
Report Rapport

Atomic Energy Control Board

Commission de contrôle de l'énergie atomique



Atomic Energy Control Board
P.O. Box 1046
Ottawa, Canada
K1P 5S9

Commission de contrôle de l'énergie atomique
C.P. 1046
Ottawa, Canada
K1P 5S9

INFO-0148-1

REPORT ON TESTS USING A FLOW VISUALIZATION RIG - TWO CHANNEL PER PASS CONFIGURATION

by

R.P. Bell and W.C. Bowman
Monserco Limited

A research report prepared for the
Atomic Energy Control Board
Ottawa, Canada

January 1985

Canada

Research report

REPORT ON TESTS USING A FLOW VISUALIZATION RIG - TWO CHANNEL PER PASS CONFIGURATION

Prepared by R.P. Bell and W.C. Bowman, Monserco Limited, under DSS file No. 02SQ.84055-3-4111.

ABSTRACT

The flow visualization rig at Monserco Limited has been modified and commissioned, and then used to conduct several tests with two channels in each pass. Single phase thermosyphoning in the rig was demonstrated, and two phase experiments with different starting conditions were done. Results of the tests are presented here. The two phase tests resulted in flow patterns with the same characteristics, independent of the starting condition. Based on results presented here, a recommendation for adding another heated channel in each pass is made.

RÉSUMÉ

L'assemblage de visualisation du débit de Monserco Limited a été modifié et mis en service pour mener plusieurs essais avec deux canaux par passage. Le thermosyphon à phase unique a bien fonctionné et on a effectué des expériences en deux phases selon différentes conditions de départ. Le présent rapport fait état des résultats. Les essais en deux phases ont donné lieu à des modèles de débit comportant les mêmes caractéristiques, indépendamment des conditions de départ. D'après les résultats présentés ici, le rapport recommande d'ajouter un autre canal chauffé dans chaque passage.

DISCLAIMER

The Atomic Energy Control Board is not responsible for the accuracy of the statements made or opinions expressed in this publication and neither the Board nor the author assume liability with respect to any damage or loss incurred as a result of the use made of the information contained in this publication.

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	FLOW VISUALIZATION RIG DESIGN	2
2.1	Component Specification	2
2.1.1	Piping	2
2.1.2	Heaters	2
2.1.3	Instrumentation	3
2.1.4	Pumps	5
2.2	Flow Visualization Rig Scaling	5
2.2.1	Heated Section	6
2.2.2	End Fittings	6
2.2.3	Feeder, Headers, Boiler and Piping	7
2.2.3.1	Feeders	8
2.2.3.2	End Fittings	8
2.2.3.3	Headers	8
2.2.3.4	Boilers	8
2.2.3.5	Piping	9
2.2.4	Total Volume	9
2.2.5	Surge Tank and Surge Line	10
2.2.6	Verification of Rig Scaling	11
3.0	FLOW VISUALIZATION RIG TEST RESULTS	13
3.1	Single Phase Test	13
3.2	Slow Power Ramp with Single Phase Starting Condition	14
3.3	Standing Start Test 1	16
3.4	Pump Trip	17
3.5	Standing Start Test 2	18
3.6	Pressure Instrumentation Test	19
4.0	CONCLUSIONS AND RECOMMENDATIONS	19

APPENDICIES

Appendix A - Description of Thermocouples

Appendix B - Description of Pressure Measurements

Appendix C - Power Measurements

Appendix D - SOPHT Input data for Rig Scaling Verification simulations

1.0 INTRODUCTION

This report documents the first phase of work performed on the flow visualization rig modified by Monserco Limited for the Atomic Energy Control Board (AECB). The work was awarded to Monserco Limited under Department of Supply and Services (DSS) contract 0SQ83-00316, titled "Modification of a Thermosyphoning Flow Visualization Rig."

The original flow visualization rig was built at Monserco for Ontario Hydro in 1981 to study single and two phase thermosyphoning in a "figure-of-eight" heat transport loop. This rig is described in Monserco report #229-1 Sept. 1981.

At this stage of the project, the flow visualization rig has been modified and some test runs have been made. These initial tests were done to commission the flow visualization rig, and to determine the hydraulic characteristics of the rig. The observed flow behaviour in the rig indicates that some further modifications are required, and thus testing has been curtailed until these new changes are implemented.

This report describes all features of the "as-built" flow visualization rig, and presents results from initial thermosyphoning tests done with the rig. A discussion of the rig behaviour is included with the test results.

2.0 FLOW VISUALIZATION RIG DESIGN

2.1 Component Specification

2.1.1 Piping

Table 2-I contains a list of components in the test loop, and specifications of the materials used for construction. Figure 2-1 is a scale drawing which can be used for locating components mentioned in Table 2-I.

The materials selection was based on the following criteria:

1) All piping must be transparent and clarity must be maintained after prolonged exposure to boiling water at 100°C.
2) Piping and couplings must retain structural strength at a temperature of 100°C.
3) Piping used for the heated sections must withstand temperatures above 100°C and stay intact in the event of heater element contact under voided conditions.
4) Piping size and shape should accommodate commercially available couplings to simplify piping re-arrangement as required during testing.

It was found that polycarbonate tubing (Lexan) best satisfied specifications 1, 2 and 4. Tests in boiling water showed that the material retained clarity and strength at 100°C. Acrylic tubing (Plexiglass) costs less than polycarbonate, however when placed in boiling water the acrylic tube became opaque. Polycarbonate tubing was chosen for its clarity and strength in test rig conditions. The tubing was readily available in a size to fit commercially available ABS compression fittings.

ABS fittings were used to connect piping in the rig. The fittings are low cost and readily available for all required connection geometries. Tests in boiling water

TABLE 2-I

COMPONENT MATERIAL SPECIFICATIONS

FOR FLOW VISUALIZATION RIG

Component	Material	Size (cm)	
		ID	OD
Heated Channel	Pyrex	2.64	2.39
Feeders	Poly C.	2.54	3.17
Headers	Poly C.	9.52	10.16
Steam Generator			
Tubes	Poly C.	.95	1.27
Shell	Acrylic	10.16	11.43
Heater	Incoloy		.95

and experience with the visualization rig showed that the ABS fittings do soften when immersed in boiling water for long periods. They do, however, maintain sufficient structural strength to prevent leakage at connections in the rig when the connected pipes are anchored securely to a backboard.

Acrylic tubing was used for the steam generator shell because of the required tube size. The four inch (120 mm) I.D. tubing was readily available in acrylic (but not polycarbonate). The shell side of the steam generator is about 30°C cooler than the tubes during rig operation, and thus the temperature is low enough to maintain clarity.

The heated fuel channel sections were made of pyrex tubing because of the potential for contact with the hot heater elements. Pyrex is much more fragile than the polycarbonate tubing, making fuel channel assembly a delicate operation, however the tubing easily withstands the high temperatures encountered in the channels. Pyrex tubing was available with an outside diameter for compatability with the ABS fittings.

2.1.2 Heaters

Three commercially available indirect heaters were used in each heated channel. The heaters are straight tubular Incoloy elements with a 120 volt, 1 kW rating.

The heaters have a 2.9 m sheath length with .69 m cold ends. Rig operation to date has proven good heater durability under the full range of operating conditions.

2.1.3 Instrumentation

The flow visualization rig is instrumented to monitor and record primary coolant pressure, temperature, power and flow during a test. Secondary coolant temperature and flow is measured.

Signals from the instruments are input to a Hewlett-Packard 3497A data logger. An HP85A microcomputer controls the 3497A through an HP-1B interface. On command from the controller, the 3497A receives inputs from the test rig sensors, measures the input data and outputs the measurements through the HP-1B to the HP85A. The HP85A controller can be used to process and display the data, however in the system at Monserco the data is sent to the in-house VAX 11/750 computer for processing. The VAX system is faster, and large data files can be stored for plotting after an experiment is complete. The VAX computer is connected to a VT100 interactive terminal situated next to the rig and processed data is transmitted to the terminal while the rig is running. This allows continuous monitoring of the test in progress.

Thermocouple and pressure transducer locations in the rig are shown in figure 2-1. Appendices A and B provide detailed descriptions of temperature and pressure instrumentation respectively.

Power measurements are made for each pair of heated channels, (1 & 2, 3 & 4). Appendix C provides a description of the power measuring circuit.

A turbine flow meter is available for insertion in the loop. The instrument is easily fitted into any straight run of pipe in the loop. Water passing through the flowmeter turns the impeller which generates 10 mV pulses, with frequency proportional to the flow rate. A model 44426A 100 kHz reciprocal counter assembly is used by the data logger to count pulses from the flow meter over a time interval specified in the controller program.

2.1.4 Pumps

Two automotive water pumps are used on the flow visualization rig. The pumps are driven with D.C. motors through universal joints constructed with plastic tubing. A variable power supply feeds the pump motors to allow gradual flow rundown for approaching thermosyphoning conditions in the loop.

The flow/head characteristic for the pumps was not available from the supplier, and has not been determined at this time. However, the pumps easily provide sufficient flow to transport full heater power to the boilers.

2.2 Flow Visualization Rig Scaling

The flow visualization rig was originally scaled to have approximately the same power to volume ratio as the CANDU 600 MW reactor at decay power level. During construction of the rig, deviations from the true volumetric scaling were made to accommodate commercially available plastic pipe and fittings, and to include horizontal sections in the feeders. This section describes scaling of the rig in its final assembled configuration.

During natural circulation cooling, the driving force for coolant flow is proportional to the density difference in the hot and cold legs and the elevation change around the loop. The flow visualization rig was designed to have the capability for giving the same mass flux in the heated section as that occurring in a 600 MW reactor during natural circulation cooling. To provide the capability for varying rig mass flux, the backboard was hinged so the rig can be operated at any angle between horizontal and vertical. A rig channel mass flux similar to that in the

real reactor gives comparable temperature gradients, and provides similar dynamic behaviour in the rig to that in the real reactor (same power/volume ratio). The SOPHT program was used to simulate the rig and the 600 MW reactor to verify the design. The results of the simulations are presented here.

2.2.1 Heated Section

The heated channels were scaled to give approximately the same channel power density in the rig as that in the CANDU 600 MW reactors at decay power level. For the 600 MW reactor,

Total Core Volume = 8.8 m^3

Decay Power (2%) = 4.11×10^4 kW

Power Density = 4670 kW/m^3

A rig channel length of 2.84 m was chosen to fit on the existing backboard. The heater elements have 0.69 m cold ends (to model end fittings) giving a heated length of 1.46 m. Heater element cross sectional area is $7.13 \times 10^{-5} m^2$, and therefore the heated volume in the four fuel channels is

$$\left(\frac{\pi}{4} \times .0264^2 - 3 \times 7.13 \times 10^{-5}\right) \times 4 \times 1.46 = .00195 \ m^3$$

The power density at 10 kW is: $\frac{10 kW}{.00195 m^3} = 5128 \frac{kW}{m^3}$

2.2.2 Overall Elevation Scaling

An objective of the initial scaling of the flow visualization rig was to achieve the same mass flux in the rig and 600 MW reactor fuel channels under single phase natural circulation conditions. The relationship governing flow in the loop for all components in each pass is:

$$(\rho_H - \rho_C) g \Delta H = \sum_i \left(\frac{K + \frac{fl}{d}}{2\rho} \right)_i G_i^2$$

where ρ_H = hot leg density
ρ_C = cold leg density
g = gravitational constant
ΔH = hot/cold leg elevation change
G = mass flux
ρ = average coolant density
$K+\frac{fl}{d}$ = head loss factor

The rig was built with a total elevation of 4.6 m from the centre of the core to the top of the boilers. This is approximately a quarter of the full scale elevation. This height could be accommodated in the existing space. The backboard was designed to be lowered to vary elevation driving head if required. No attempt was made to adjust frictional pressure drop in the design. Changing backboard attitude varies ΔH, which changes G in the above equation. SOPHT simulations showed that rig channel mass flux with a vertical orientation is in good agreement with the 600 MW reactor value, and thus the vertical orientation was used for the present tests.

2.2.3 Feeder, Header, Boiler and Piping

Table 2-II shows the volume fractions for each component in the 600 MW heat transport system. In designing the flow visualization rig, attempts were made to keep volume distribution the same as the real reactor. The rig volume fractions are shown in the table.

TABLE 2-II

VOLUMETRIC FRACTIONS FOR 600 MW REACTOR

AND FLOW VISUALIZATION RIG

Component	Fraction	
	600 MW	RIG
Reactor	.080	.075
End Fittings	.068	.048
Feeders	.234	.372
Headers	.073	.195
Piping	.202	.059
Steam Generators	.346	.251

2.2.3.1 Feeders

The four inlet and four outlet feeders have a total length of 19.1 m. The feeder flow area is 5.067×10^{-4} m², and therefore the total feeder volume is 9.68×10^{-3} m³.
For true volume scaling, the feeder volume would be

$$\frac{.234}{.08} \times .00195 = 5.70 \times 10^{-3} \text{ m}^3$$

2.2.3.2 End Fittings

The unheated channel ends are .673 m long, giving a total "end fitting" volume of

$$\left(.673 \times \frac{\pi}{4} \times .0264^2 - 3 \times 7.13 \times 10^{-5}\right) \times 8$$

$$= 1.24 \times 10^{-3} \text{m}^3$$

Volumetric scaling gives a rig end fitting volume of

$$\frac{.068}{.08} \times .00195 = 1.66 \times 10^{-3} \text{m}^3$$

2.2.3.3 Headers

The inlet and outlet headers were built 0.178 m long. Therefore, the volume of the four headers is

$$\frac{4 \times \pi \times .0953^2 \times .178}{4} = 5.08 \times 10^{-3} \text{ m}^3$$

This can be compared with the ideally scaled header volume of

$$\frac{.073}{.08} \times .00195 = 1.78 \times 10^{-3} \text{m}^3$$

The as-built header volume is therefore larger than that required for volumetric scaling.

2.2.3.4 Boilers

The boilers were built with .0127 m O.D. tubes, with an inside diameter of .0095 m. Each boiler has 10 tubes, 4.6 m long, giving a total tube volume of

$$20 \times \frac{\pi \times .0095^2}{4} \times 4.6 = 6.52 \times 10^{-3} \text{m}^3$$

The ideal scaled volume is

$$\frac{.346}{.08} \times .00195 = 8.43 \times 10^{-3} m^3$$

2.2.3.5 Piping

The heat transport piping modelled in the rig consists of piping connecting the headers to the boilers (including pump volume) and the steam generator primary side inlet and outlet plenums. In the rig, piping connecting the headers to the boilers is 2.0 m long. This pipe has a volume of $\frac{\pi \times .0254^2 \times 2}{4} = 1.01 \times 10^{-3} m^3$.

The steam generator inlet and outlet plenums have a total volume of $5.2 \times 10^{-4} m^3$ and therefore total rig piping volume is $1.01 \times 10^{-3} + 5.2 \times 10^{-4} = 1.53 \times 10^{-3} m^3$. This can be compared with the volumetrically scaled value of

$$\frac{.202}{.08} \times .00195 = 4.32 \times 10^{-3} m^3$$

2.2.4 Total Volume

The previous sections show the volume distribution compared with volumetrically scaled values for each component in the flow visualization rig. For the rig, the total unheated volume is End Fitting + Feeders + Boilers + Piping + Headers

$$= 1.24 \times 10^{-3} + 9.68 \times 10^{-3} + 6.52 \times 10^{-3} + 1.53 \times 10^{-3} + 5.04 \times 10^{-3}$$

$$= .024 \ m^3$$

The volumetrically scaled unheated volume would be

$$1.66 \times 10^{-3} + 5.7 \times 10^{-3} + 8.93 \times 10^{-3} + 4.32 \times 10^{-3} + 1.78 \times 10^{-3}$$

$$= .022 \ m^3$$

Thus, total unheated rig volume is greater than the ideal volumetrically scaled value by 9 percent. The volume

distribution in the rig is somewhat different from that in the real reactor due to restrictions imposed by available materials and geometrical requirements for visualization and filming of important thermalhydraulic phenomena.

The total volume of the flow visualization rig is .024m³ and the total 600 MW reactor heat transport system volume is about 110m³, which translates to a rig:600 MW volume scale of 1:4583.

2.2.5 Surge Tank and Surge Line

The surge tank was fabricated by fitting a connection to the bottom of a .023 m³ pyrex vessel. The tank is open to atmosphere and connected to the visualization rig with flexible plastic tube. Rig pressure is controlled by raising and lowering the surge tank.

During two phase natural circulation cooling with intermittent flow, pressure fluctuations occur in the cooling system. The surge tank increases system compressibility, and thus prevents large pressure fluctuations in the system. Scaling of the surge line is important to ensure that rig dynamics are similar to those of the real reactor.

The power to volume ratio for the rig is identical to that for the 600 MW reactor, and therefore pressure fluctuations during two phase intermittent flow thermosyphoning will be similar for the same overall system pressure. A properly scaled surge line will allow the same volumetric flow (as a fraction of total) in the rig as that in the real reactor. The flow visualization rig scale is 1:4583, and therefore a given pressure drop should give a rig surge line flow to full scale surge line flow ratio of 1:4583. Assuming similar frictional pressure drop in the rig and 600-MW reactor, the ratio of rig flow area to full scale flow area should be 1:4583. The full scale surge line flow area is .056 m², and therefore the surge line for the rig

would be constructed with .004 m I.D. tubing. For a rig surge line length of 2m, and k and f values of 2 and .02 respectively, the rig head loss is k + fl/d

$$= 2 + \frac{.02 \times 2}{.004} = 12$$

The 600 MW surge line head loss is

$$6.5 + \frac{.02 \times 28.8}{.267} = 8.66.$$

The assumption of similar frictional pressure drops in the rig and 600 MW reactor surge lines is justified. The .0095 I.D. tubing used in the boilers was readily available, and this was used to build the surge line. It was decided to install a valve in the surge line to restrict flow if required for studying surge tank effects on natural circulation cooling.

2.2.6 Verification of Rig Scaling

As shown in section 2.2.2, mass flux in any component in the rig is determined by head loss coefficients around the loop, by total elevation change, and by hot/cold leg density difference. Hand calculations to verify the rig design are difficult, and thus a model of the rig was developed for the SOPHT code to verify the design. A 600 MW SOPHT model was also set up for thermosyphoning simulations to compare with the rig results. The input data for the 600 MW reactor and the flow visualization rig are contained in Appendix D.

Three cases were simulated for the 600 MW reactor and the experimental rig. Single phase thermosyphoning at low temperature (<100°C) and low pressure (<200 kPa) was simulated to compare rig performance in its expected operating conditions to that of the 600 MW reactor. Single phase thermosyphoning at high temperature (>250°C) and high pressure (>9MPa) was simulated for comparison with the low pressure results. SOPHT was also used to simulate the rig and the 600 MW reactor under two phase flow conditions at a pressure of 6.6 MPa. This work was done for comparing

two phase rig performance with that of the 600 MW reactor. This is important for understanding two phase experiments done with the rig.

Figures 2-2 and 2-3 show results of the SOPHT simulations. In single phase, channel mass flux for the rig is less than that for the 600 MW reactor, by 9% and 4% for the cold and hot thermosyphoning cases respectively. The simulations served to verify that the flow visualization rig will have a channel mass flux similar to the 600 MW reactor in single phase thermosyphoning conditions.

The SOPHT modelling shows that the rig has a somewhat different flow characteristic under two phase conditions as shown in figure 2-3. Two phase flow affects frictional head loss and the hot/cold leg density difference. Proper scaling for two phase flow would require more detailed simulations to obtain the proper combination of rig elevation and the frictional head loss for similarity with the 600 MW reactor.

FIGURE 2-1: SCALE DRAWING OF FLOW VISUALIZATION RIG

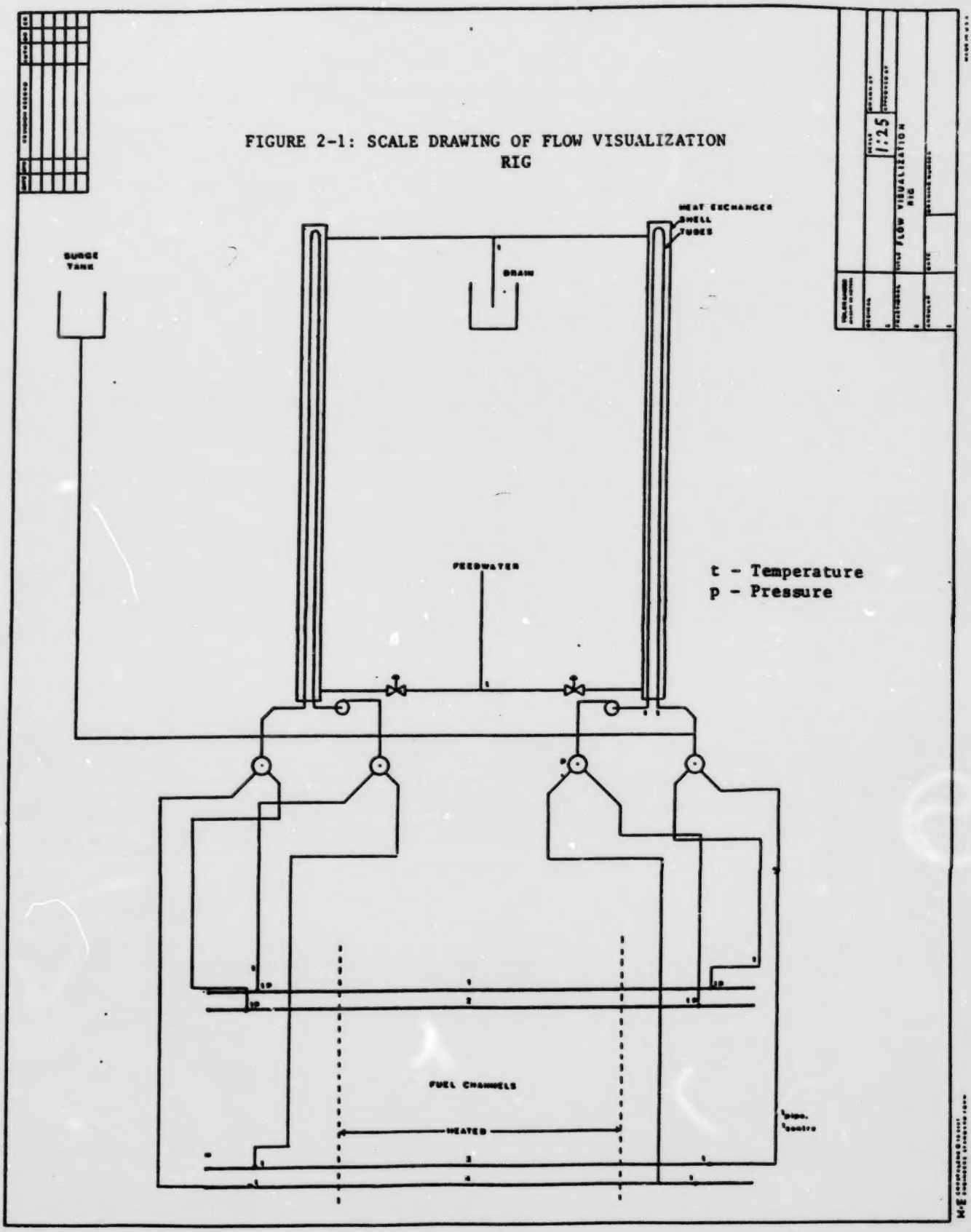


FIGURE 2-2: SINGLE PHASE CHANNEL MASS FLUX

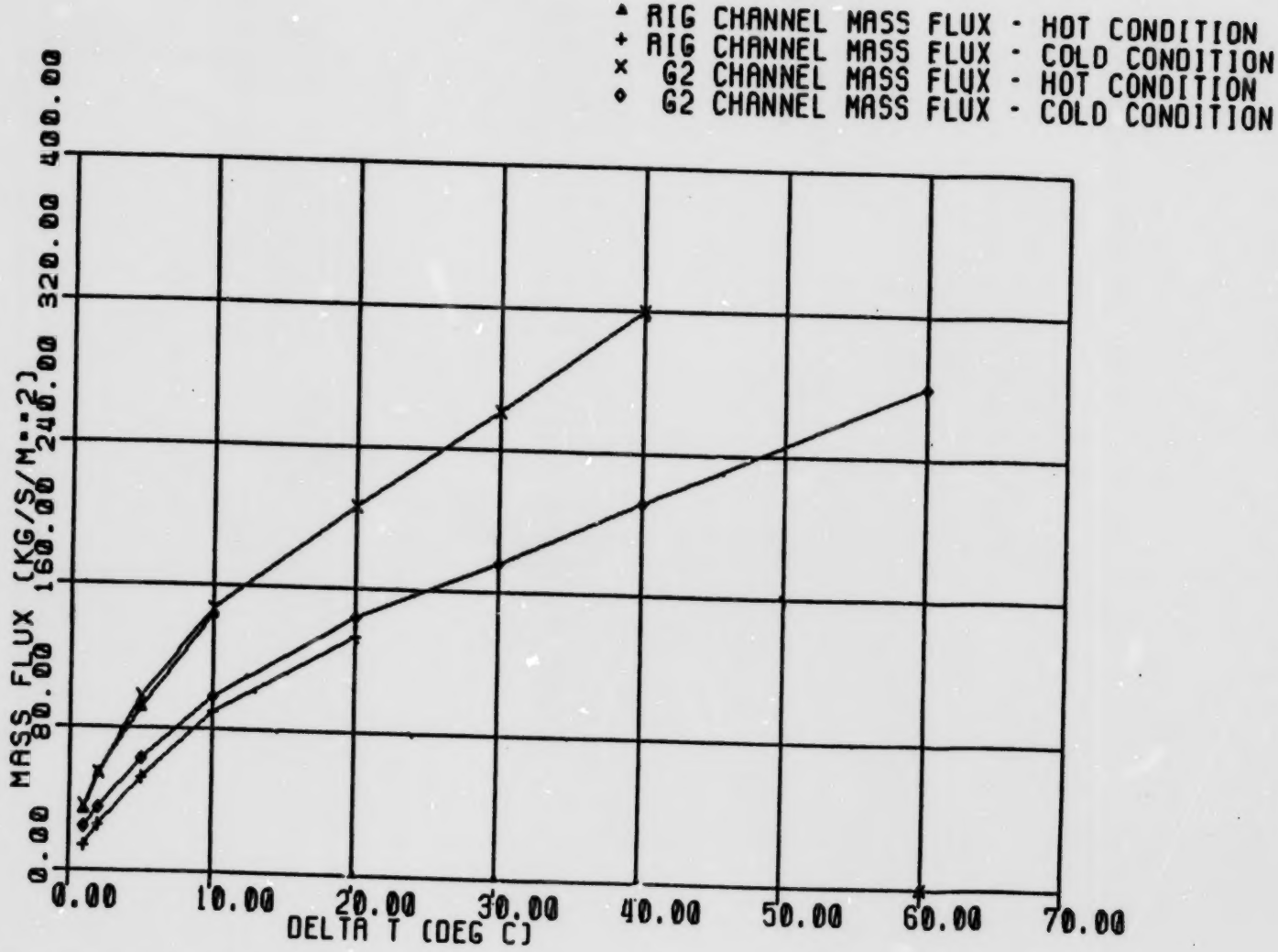
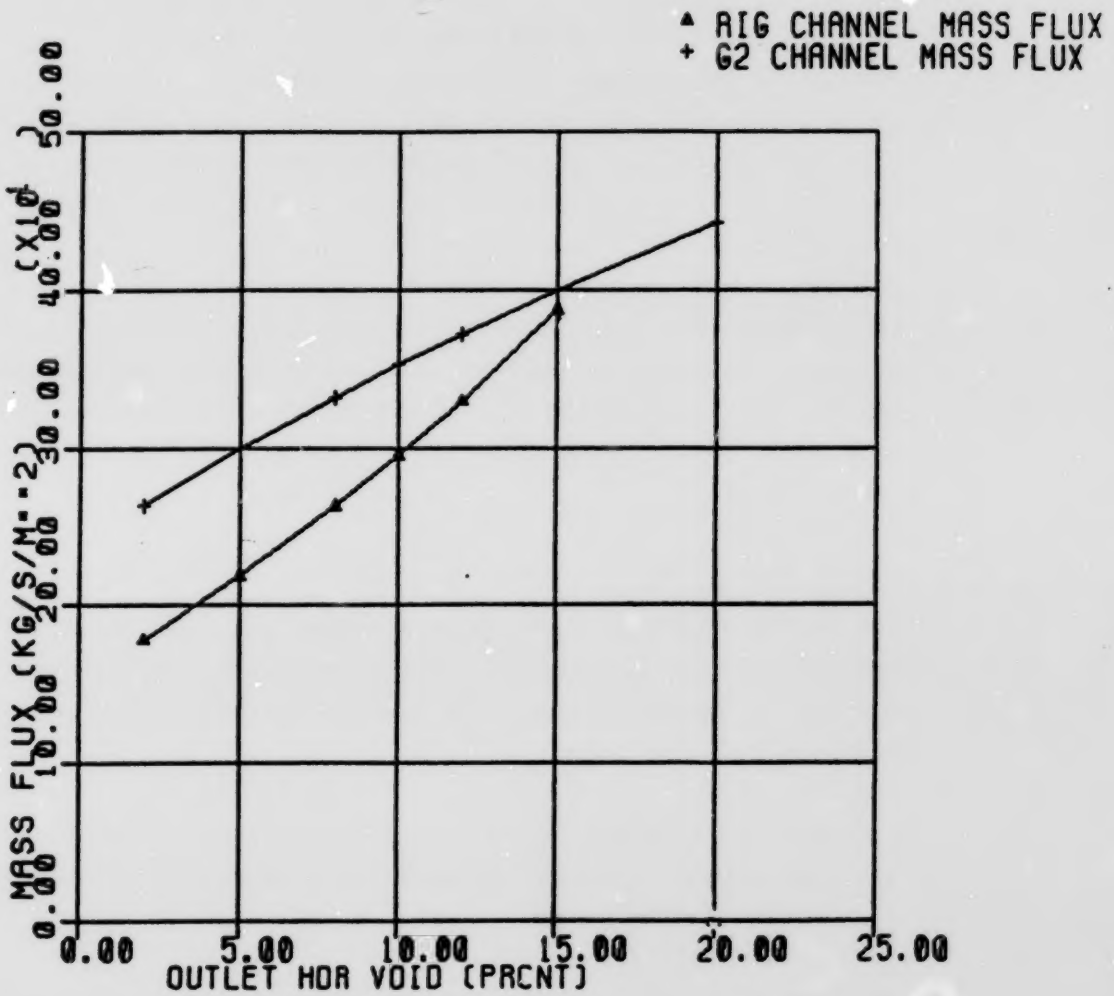


FIGURE 2-3: TWO PHASE CHARACTERISTIC



3. FLOW VISUALIZATION RIG TEST RESULTS

The flow visualization experiments described here were done primarily to determine the basic thermalhydraulic characteristics of the rig, to gain experience operating the facility, and to provide data for planning a comprehensive test matrix. The tests produced important data about rig design and thermalhydraulic behaviour.

Results from this initial set of tests led to questions about two phase thermosyphoning which can only be answered by altering the design of the rig. A contract extension from DSS will allow the modifications to be made before the full test matrix and videotaping of the test rig are done.

The tests are described here and comments on the results are given. For the first three tests described here, temperature instrumentation was operational, but the pressure and differential pressure measurements were not made. The last two tests were done with the pressure instrumentation functioning.

3.1 Single Phase Test

The single phase thermosyphoning test was done to determine temperatures around the loop for comparison with single phase rig design calculations. The following procedure was followed for the test:

(1) The rig was heated to a temperature of about 80°C with the pumps running. Figure 3.1-5 shows the channel 1 outlet temperature.

(2) The data acquisition system was started, and after 900 s the pumps were shut off and power was lowered to about 4 kW. The power level was chosen to be below that required to cause boiling in the heated channels.

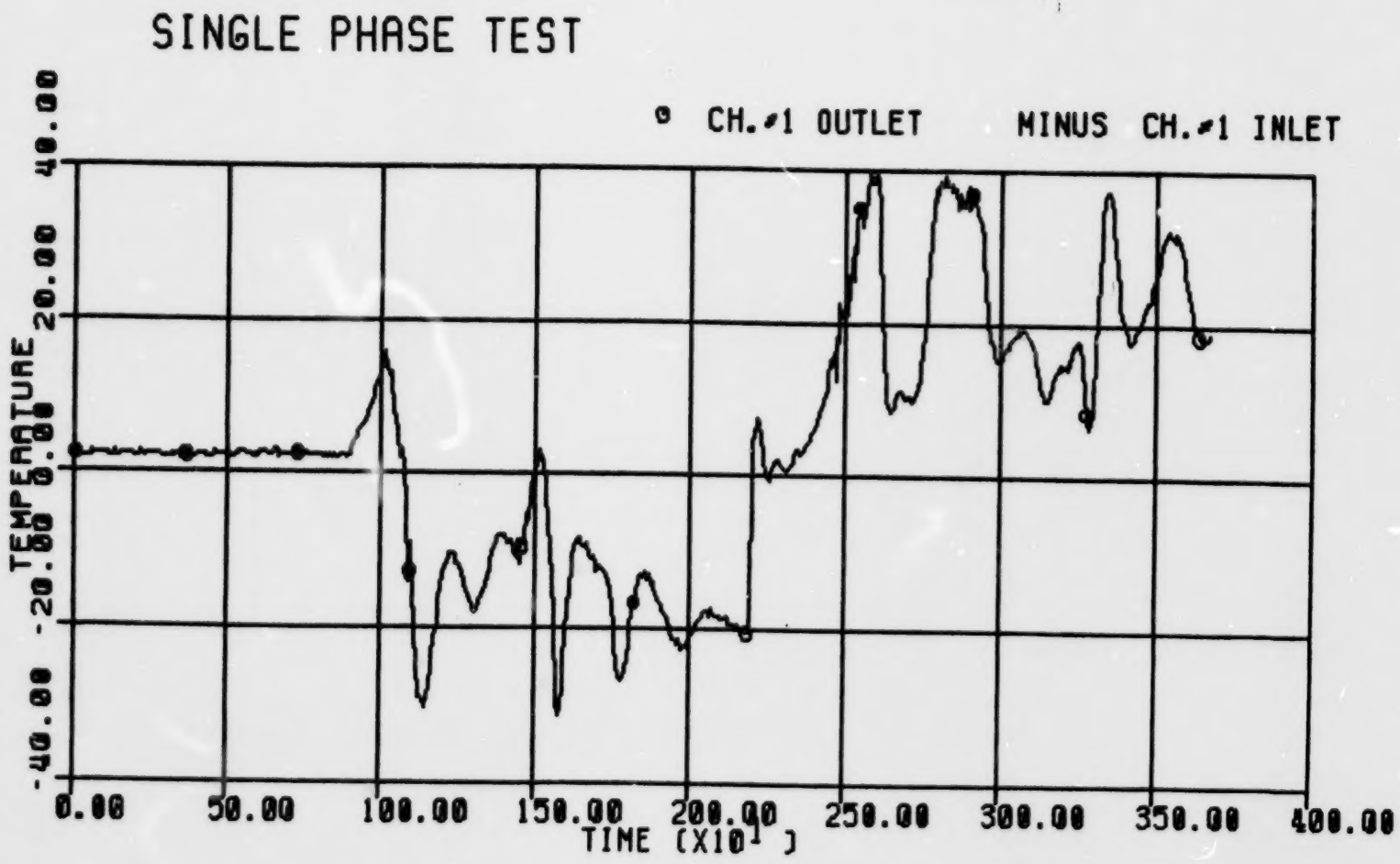

SINGLE PHASE TEST
CH.#1 OUTLET MINUS CH.#1 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.1-1

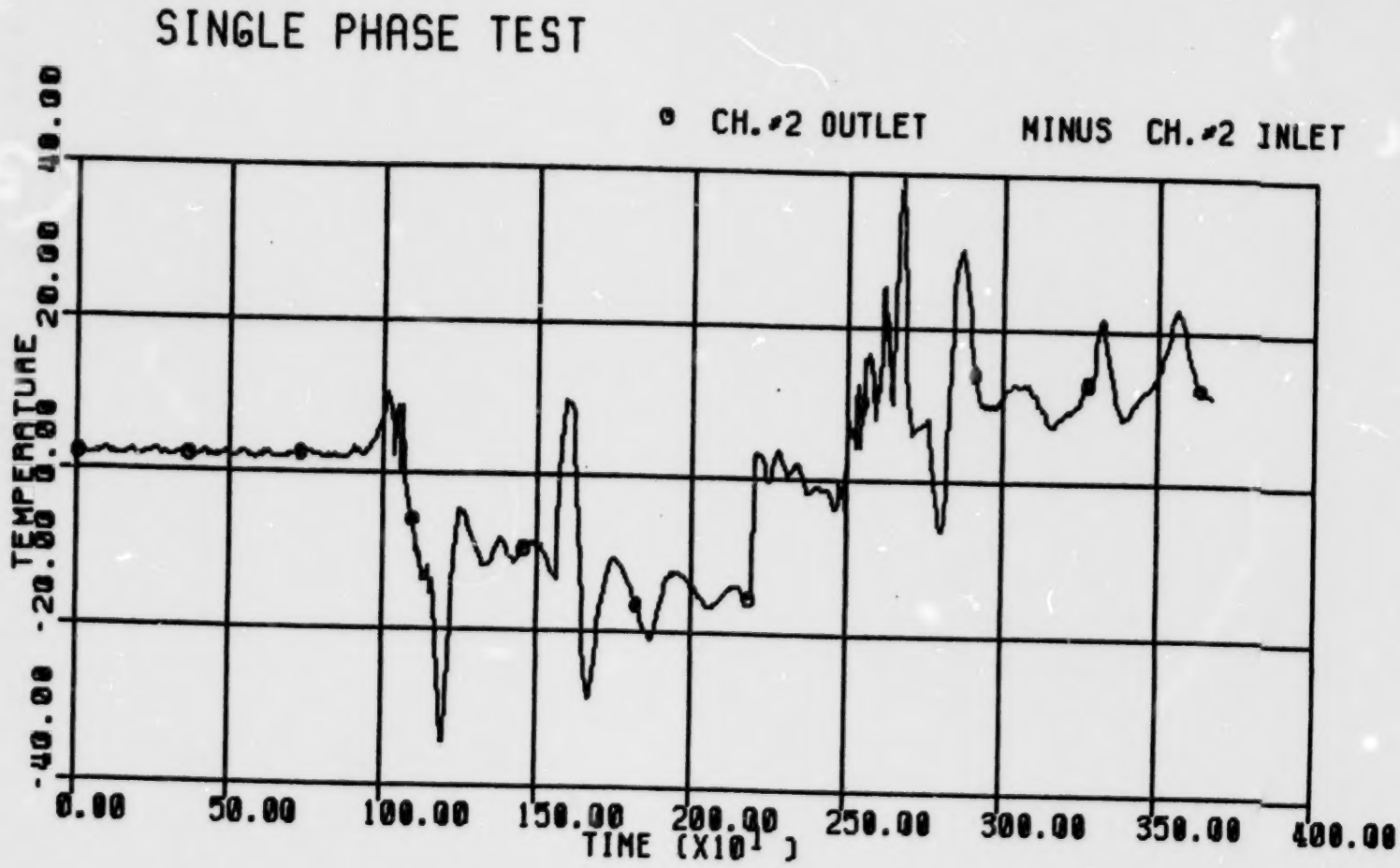

SINGLE PHASE TEST
CH.#2 OUTLET
MINUS CH.#2 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.1-2

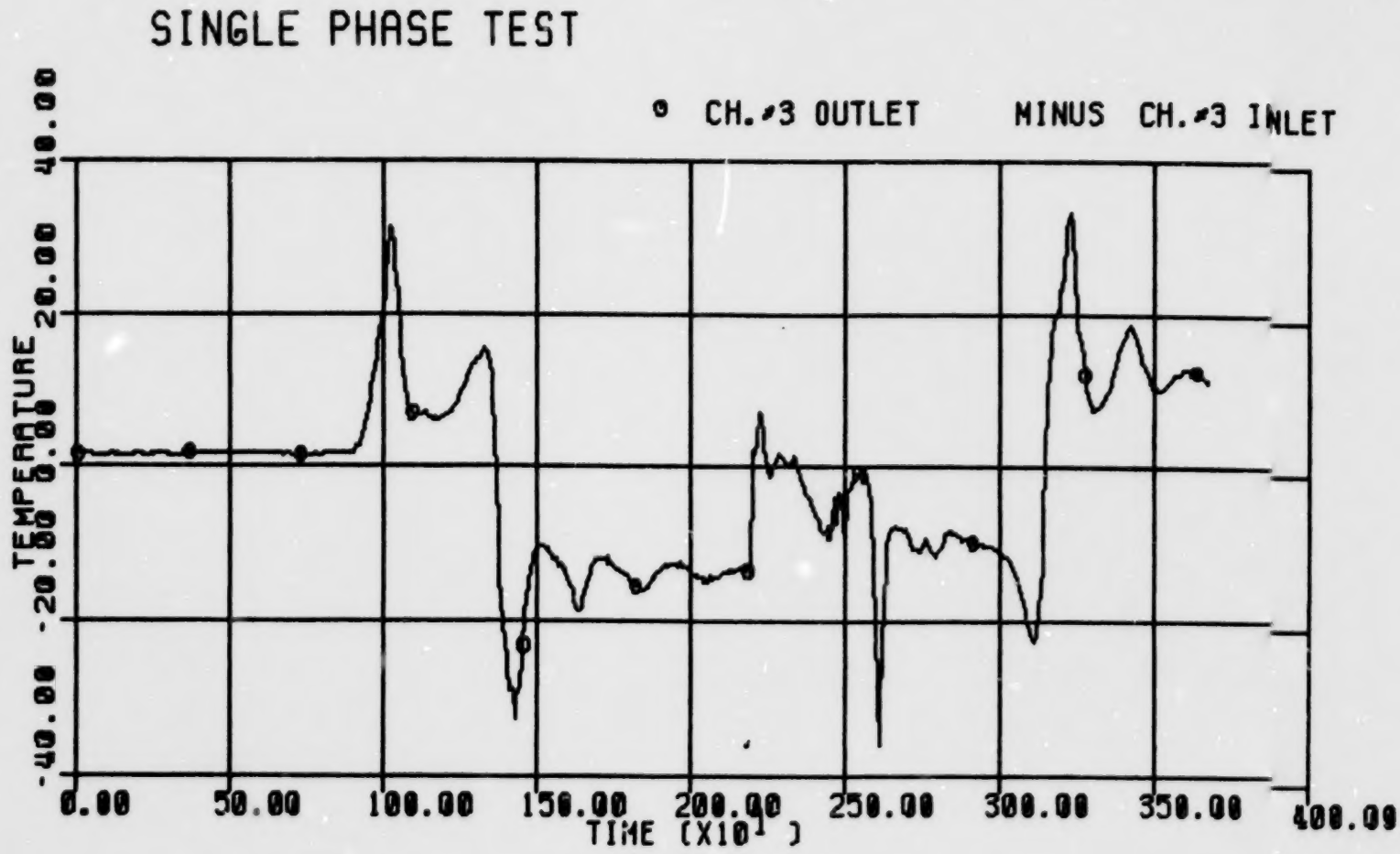

SINGLE PHASE TEST
CH.#3 OUTLET MINUS CH.#3 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.1-3

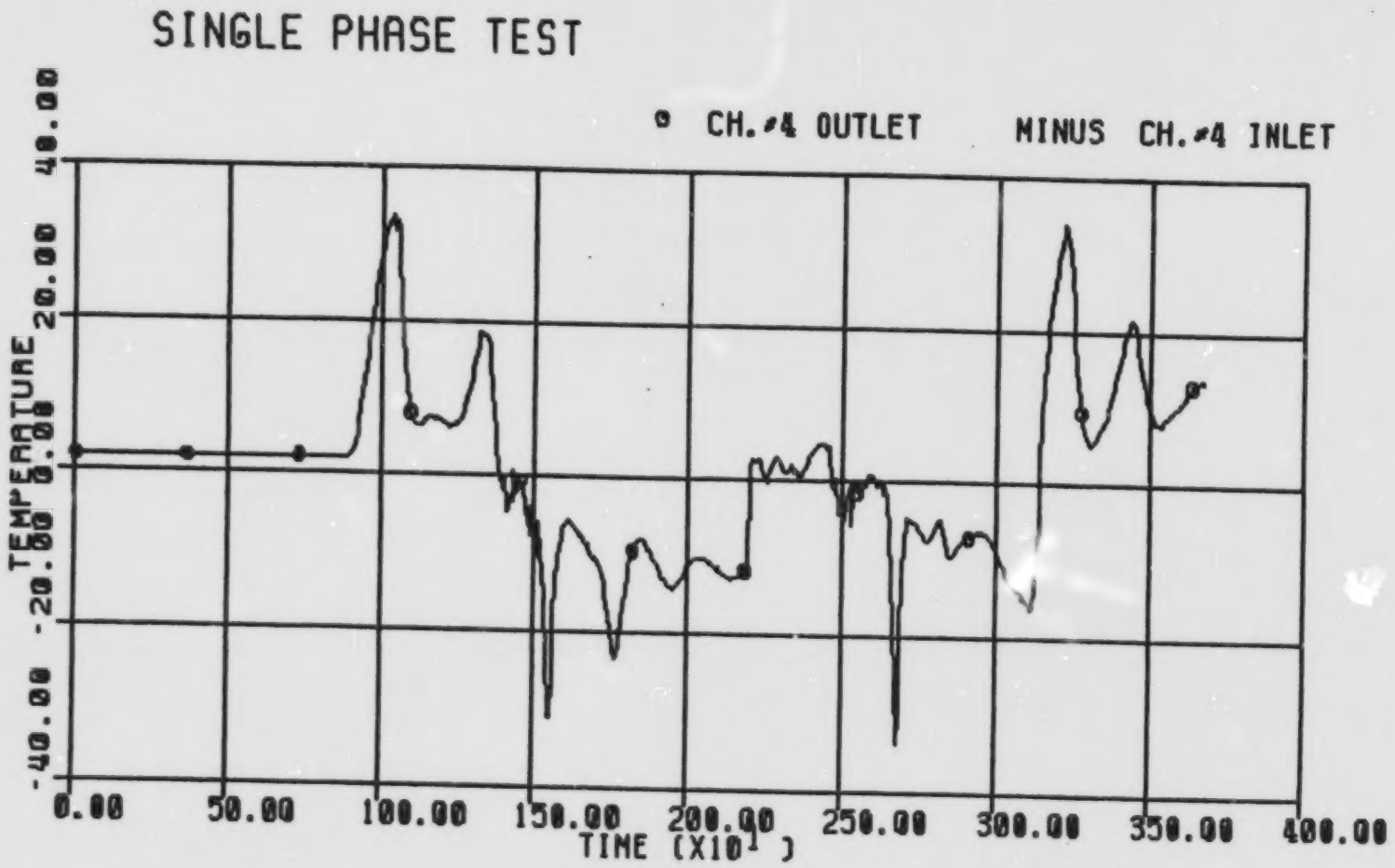

SINGLE PHASE TEST
CH.#4 OUTLET MINUS CH.#4 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.1-4

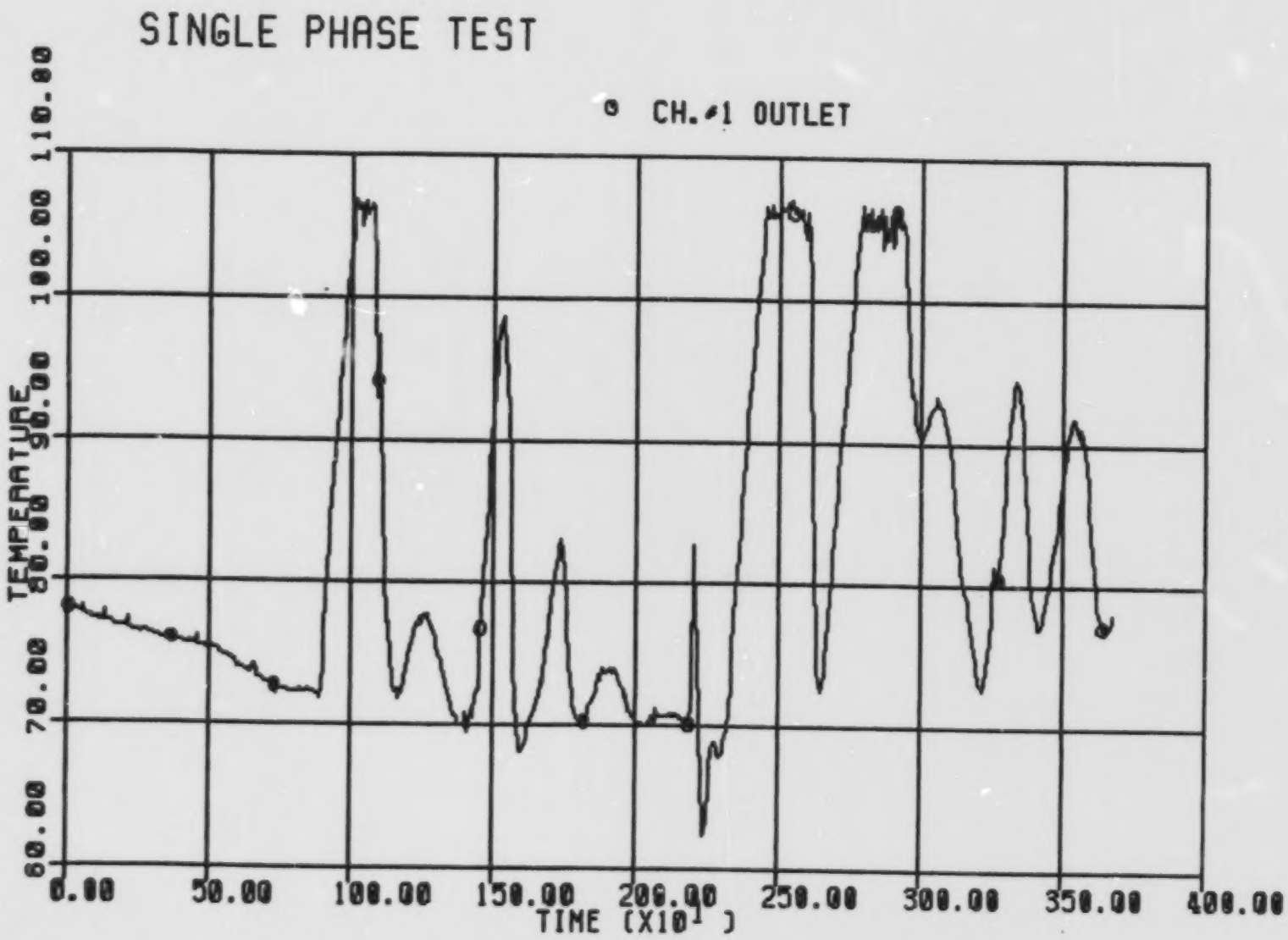

SINGLE PHASE TEST
CH.#1 OUTLET
TEMPERATURE
60.00
70.00
80.00
90.00
100.00
110.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.1-5

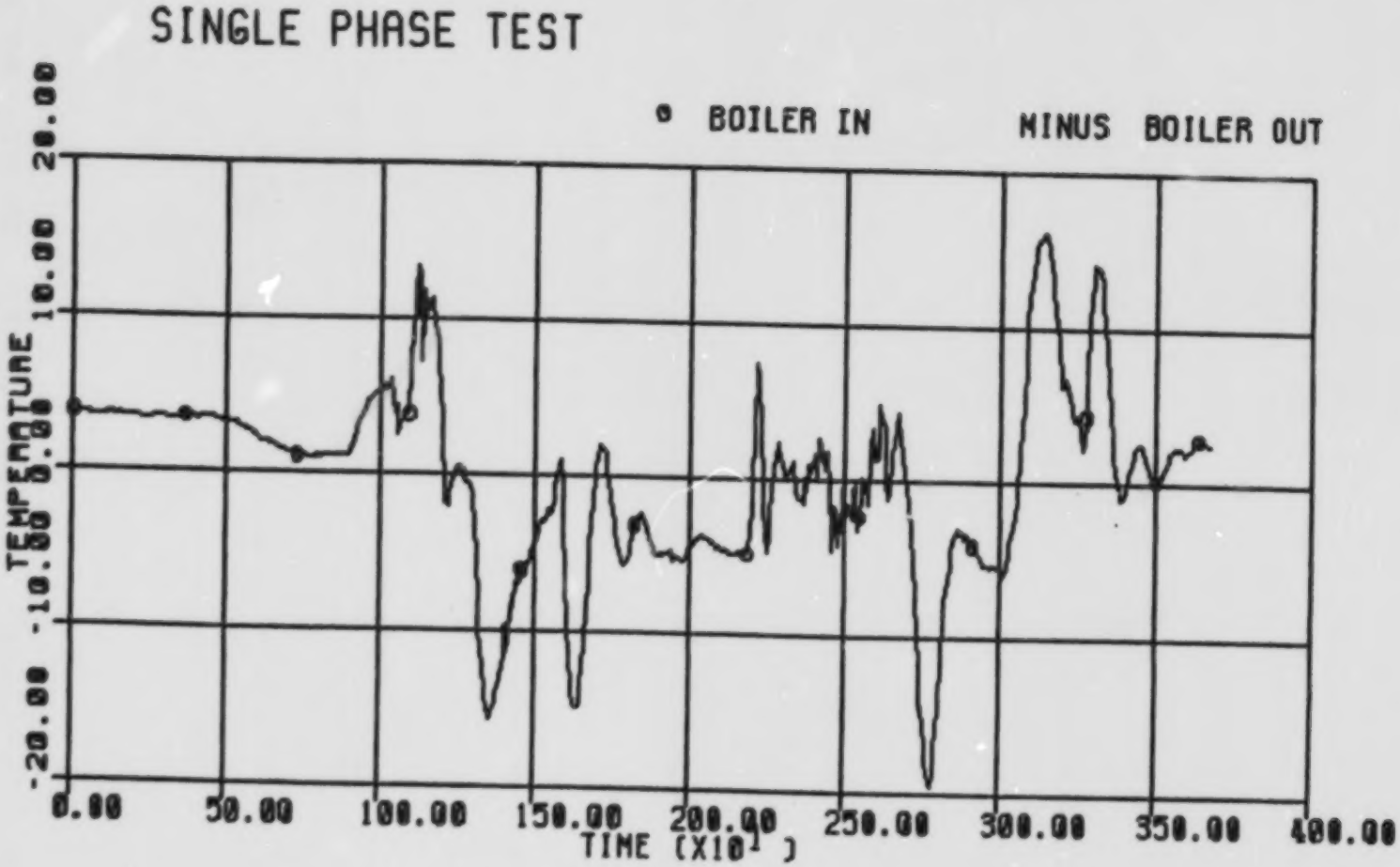

SINGLE PHASE TEST
BOILER IN
MINUS BOILER OUT
20.00
10.00
-10.00
-20.00
TEMPERATURE
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10)

FIGURE 3.1-6

(3) 2200s after data logging was started, the pumps were re-started to establish flow in the forward direction. The pumps were then shut off and natural circulation was again allowed to cool the system.

The following observations were made during the test:

(1) Immediately after pump shutdown with power at 4 kW, a small amount of boiling occurred in the heated channels. This was due to total removal of all driving forces in the system. With the pumps running, there are very low buoyancy forces (very small temperature gradients) and the pumps were stopped instantly for this test. Therefore, following pump trip, flow in the heated sections went through a short period of stagnation, causing boiling.

(2) By 1500s, a uni-directional single phase flow was established in the reverse direction. Figures 3.1-1 to 3.1-4 show outlet minus inlet temperature for each channel. The negative values indicate reverse flow. Figure 3.1-6 shows temperature difference between boiler inlet and outlet, providing further indication of reverse flow in the system at 1500s.

(3) After 2200s when the pumps had re-established forward flow and were again shut off, some boiling was again observed. During the interval between 2200s and 3200s, channels 3 and 4 experienced reverse flow. By 3200s single phase flow in the forward direction was established. The channel temperature differences shown in figures 3.1-1 to 3.1-4 are positive, indicating forward flow.

3.2 Slow Power Ramp with Single Phase Starting Condition

This test was done to establish the maximum rig power which can be removed by single phase thermosyphoning. The following procedure was followed for the test:

(1) The single phase, forward flow condition established at the end of the previous single phase test was used as a starting condition. Data acquisition was started, and at 100s, power was increased to 4.2 kW.

(2) At 400s, power was raised to 5.4 kW, and temperatures were allowed to stabilize at a new higher value.

(3) At 800s, power was raised to 6.8 kW.

(4) At 1150s, power was increased for the last time to 7.3 kW, and system behaviour was observed.

(5) During single phase thermosyphoning after the final power increase, a flow measurement was made by timing a small plastic cutting entrained in the liquid.

The following observations were made during the slow power ramp experiment:

(1) Figures 3.2-1 to 3.2-8 show temperatures logged during the experiment. The heated channels began to boil between 1500s and 2000s. At this stage of the test, heater power was 7.3 kW, indicating that single phase thermosyphoning can remove about 7kW in the rig. This heat removal was achieved with a slow power ramp, and a more rapid power increase could drive the system into boiling and unstable flow at lower power.

(2) Figure 3.2-6 shows secondary feedwater temperature rise across the boiler. Boiler power increases up to 2500s, and then drops. At about 2500s, flow through the boiler tubes is disrupted as shown in figure 3.2-5, due to boiling in the heated channels. This causes the drop in boiler power. The flow pattern in two phase can be deduced from figures 3.2-1 to 3.2-4. Forward flow occurs in channels 1 and 4, and reverse flow occurs in 2 and 3. Flow is oscillatory in the boiler as shown in figure 3.2-5.

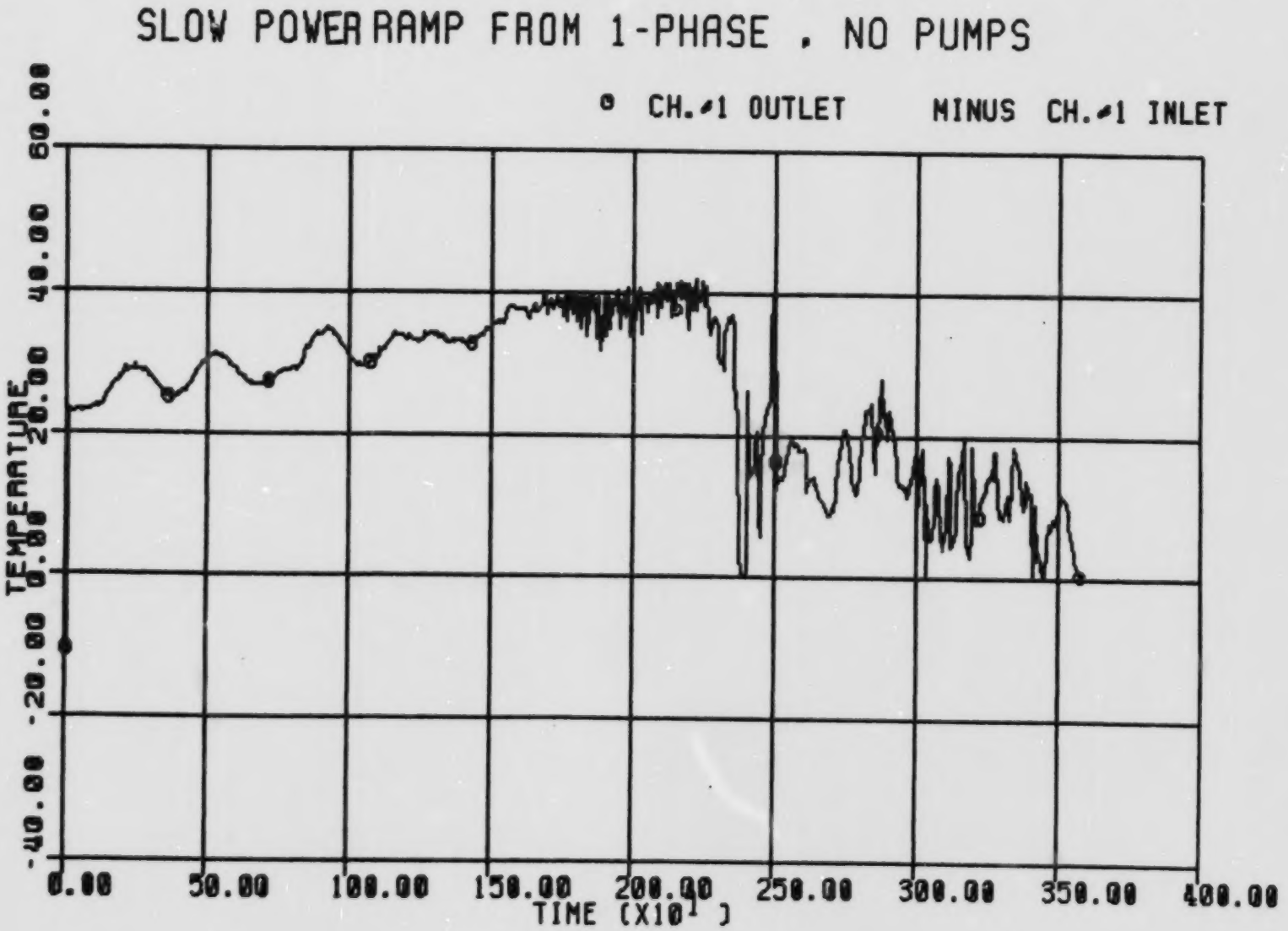

SLOW POWER RAMP FROM 1-PHASE , NO PUMPS
CH.#1 OUTLET MINUS CH.#1 INLET
TEMPERATURE
60.00
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10)

FIGURE 3.2-1

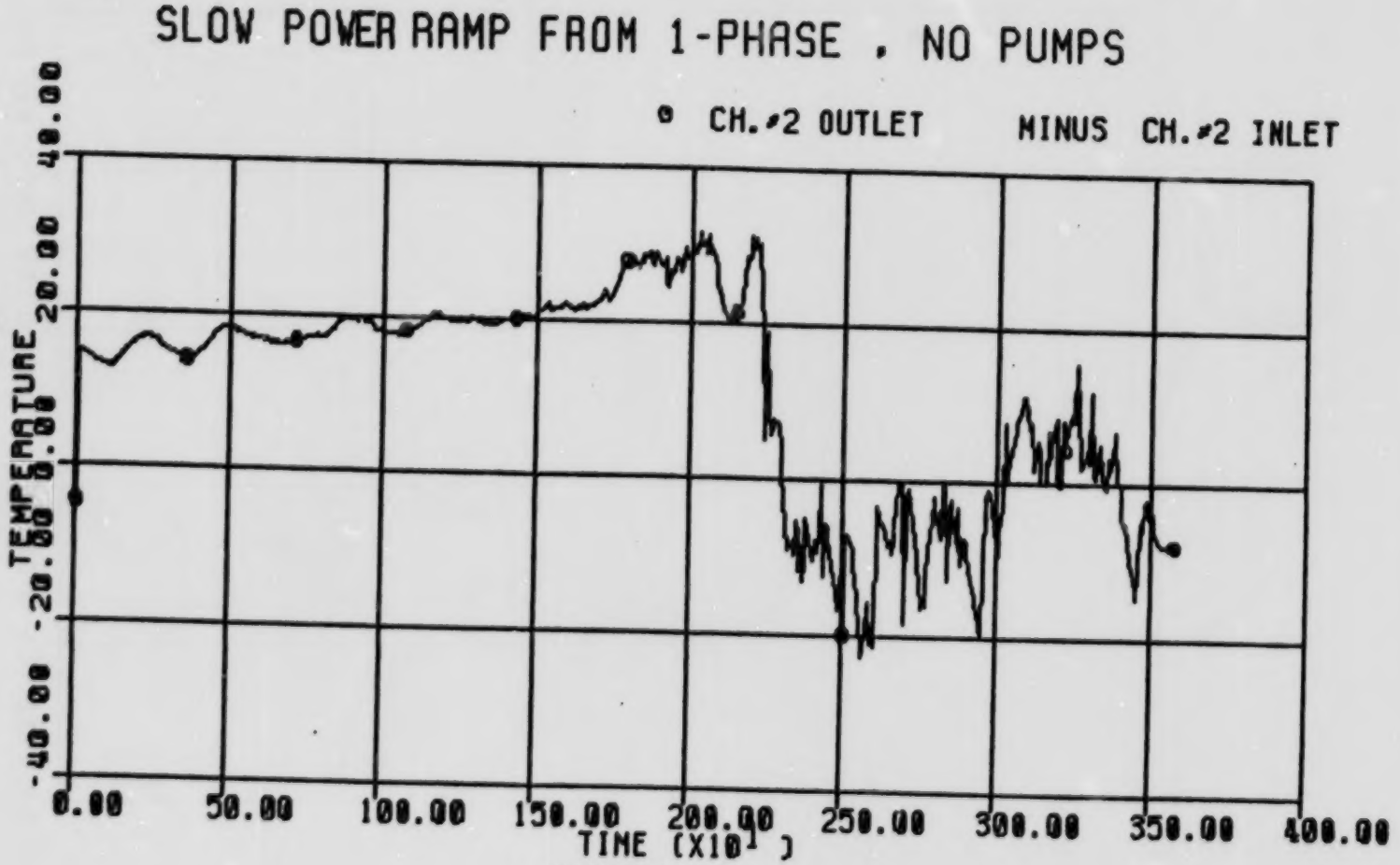

SLOW POWER RAMP FROM 1-PHASE , NO PUMPS
CH.#2 OUTLET MINUS CH.#2 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.2-2

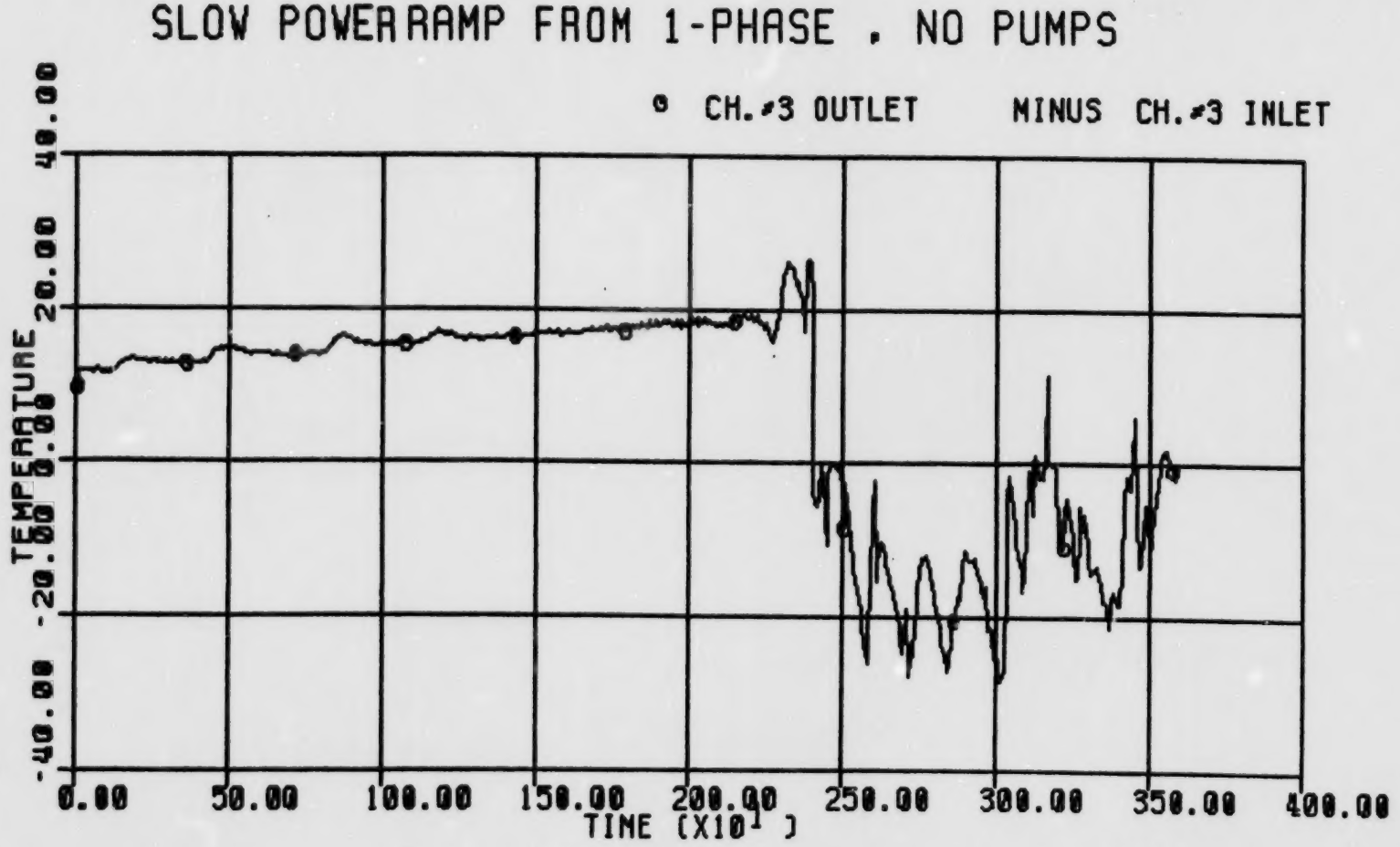

SLOW POWER RAMP FROM 1-PHASE , NO PUMPS
CH.#3 OUTLET MINUS CH.#3 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10)

FIGURE 3.2-3

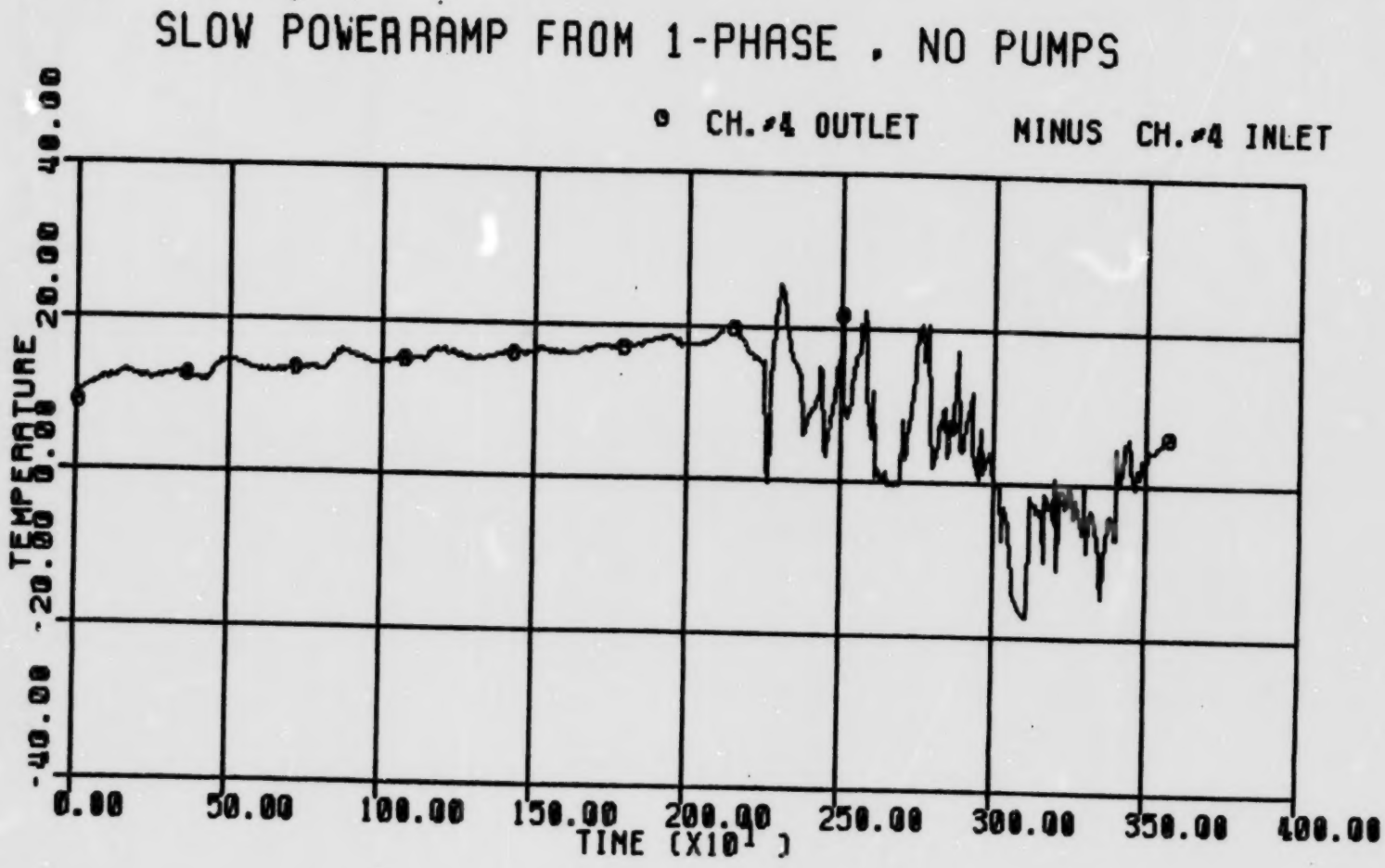

SLOW POWERRAMP FROM 1-PHASE . NO PUMPS
CH.#4 OUTLET MINUS CH.#4 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10)

FIGURE 3.2-4

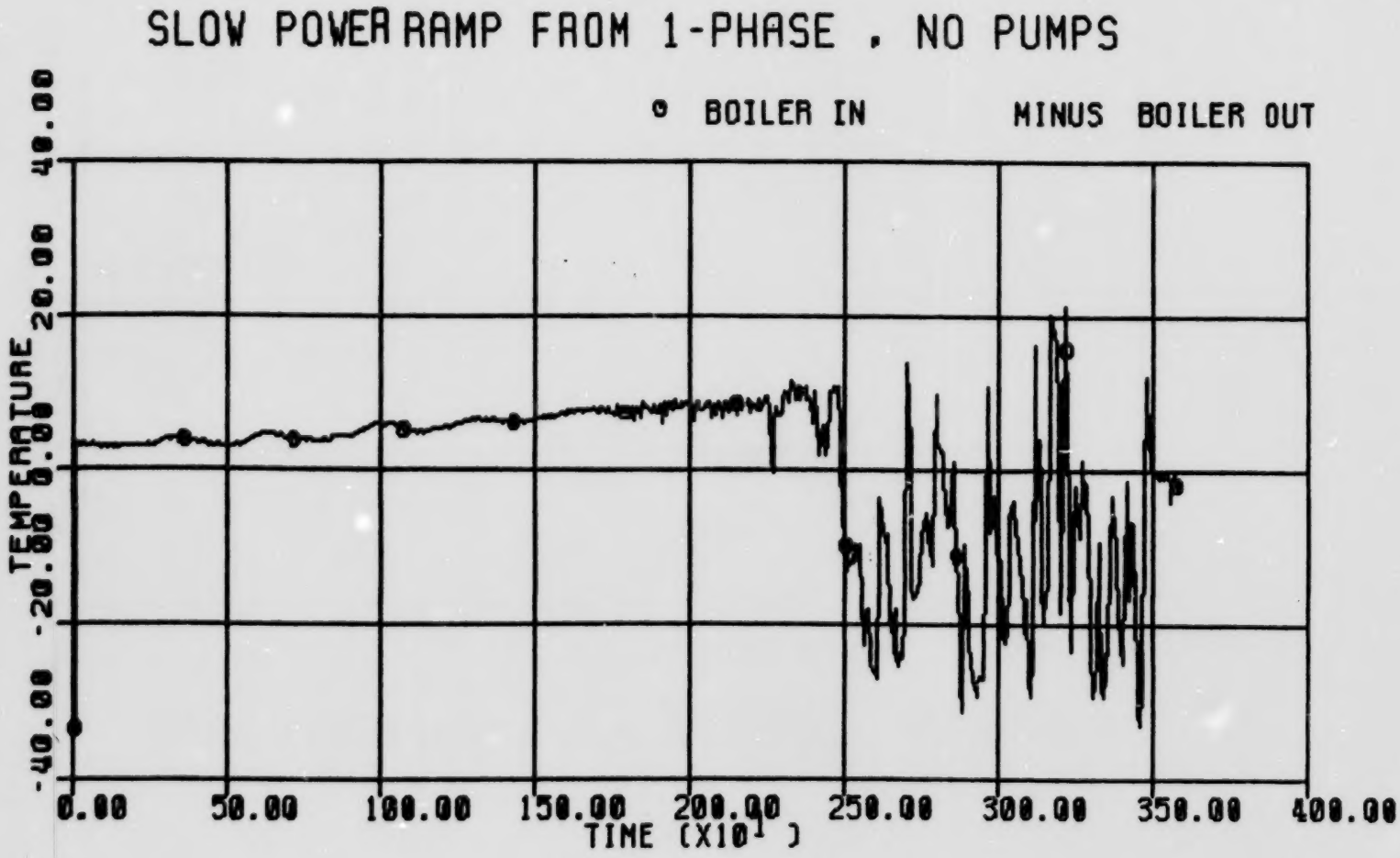

SLOW POWER RAMP FROM 1-PHASE , NO PUMPS
BOILER IN
MINUS BOILER OUT
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10)

FIGURE 3.2-5

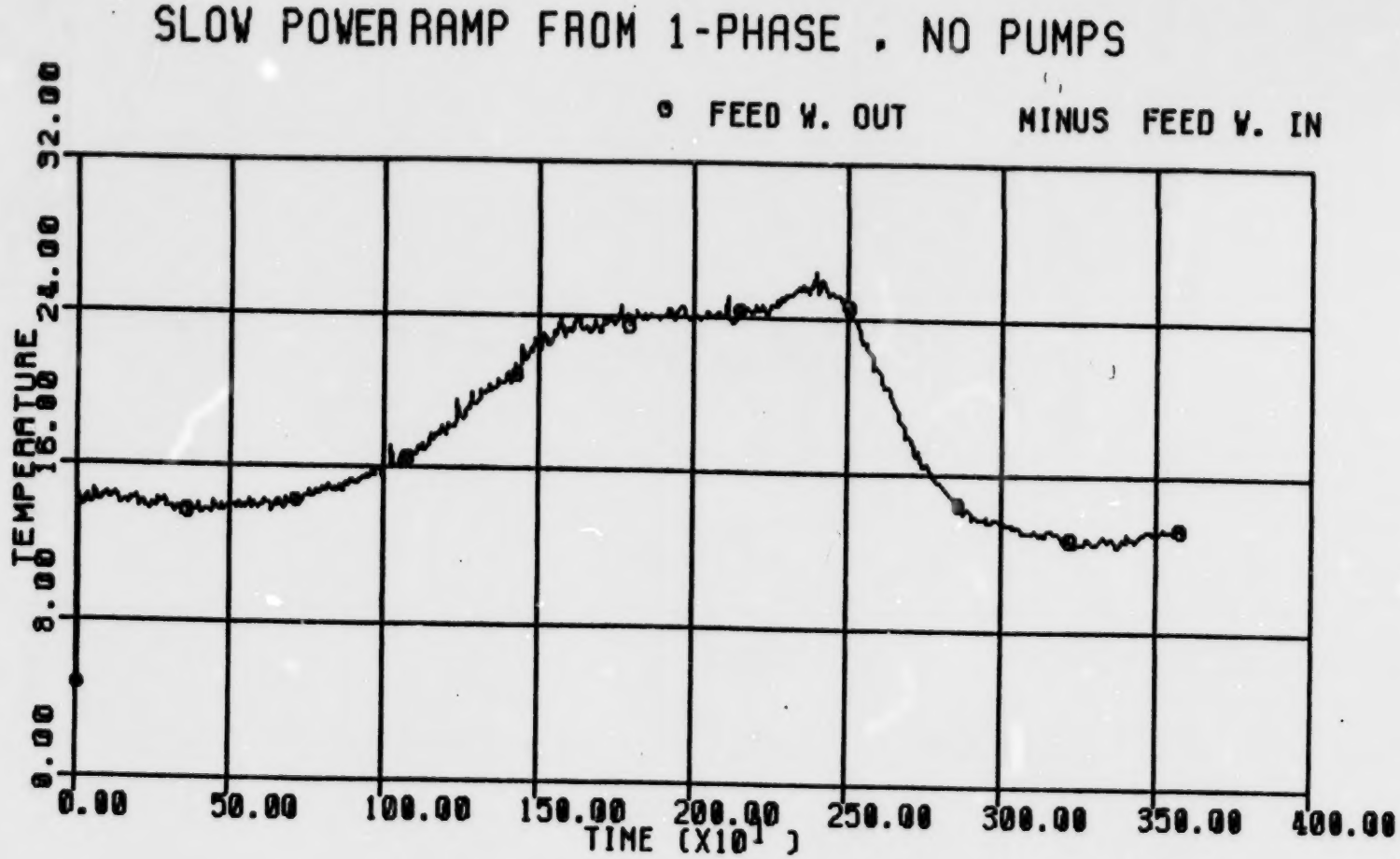

SLOW POWER RAMP FROM 1-PHASE , NO PUMPS
FEED W. OUT
MINUS FEED W. IN
TEMPERATURE
32.00
24.00
16.00
8.00
0.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10)

FIGURE 3.2-6

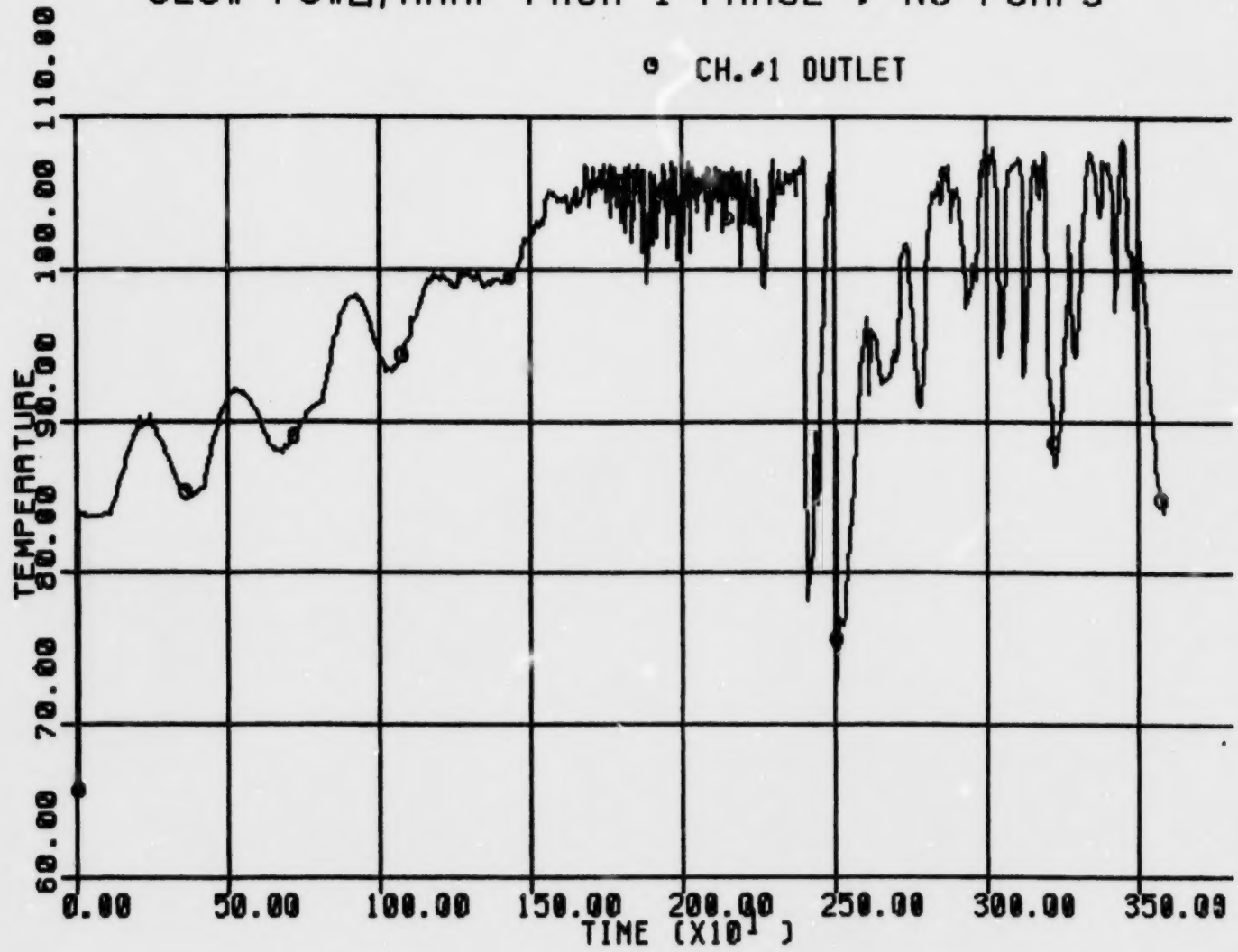

SLOW POWER RAMP FROM 1-PHASE , NO PUMPS
CH. #1 OUTLET
TEMPERATURE
60.00
70.00
80.00
90.00
100.00
110.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
TIME (X10)

FIGURE 3.2-7

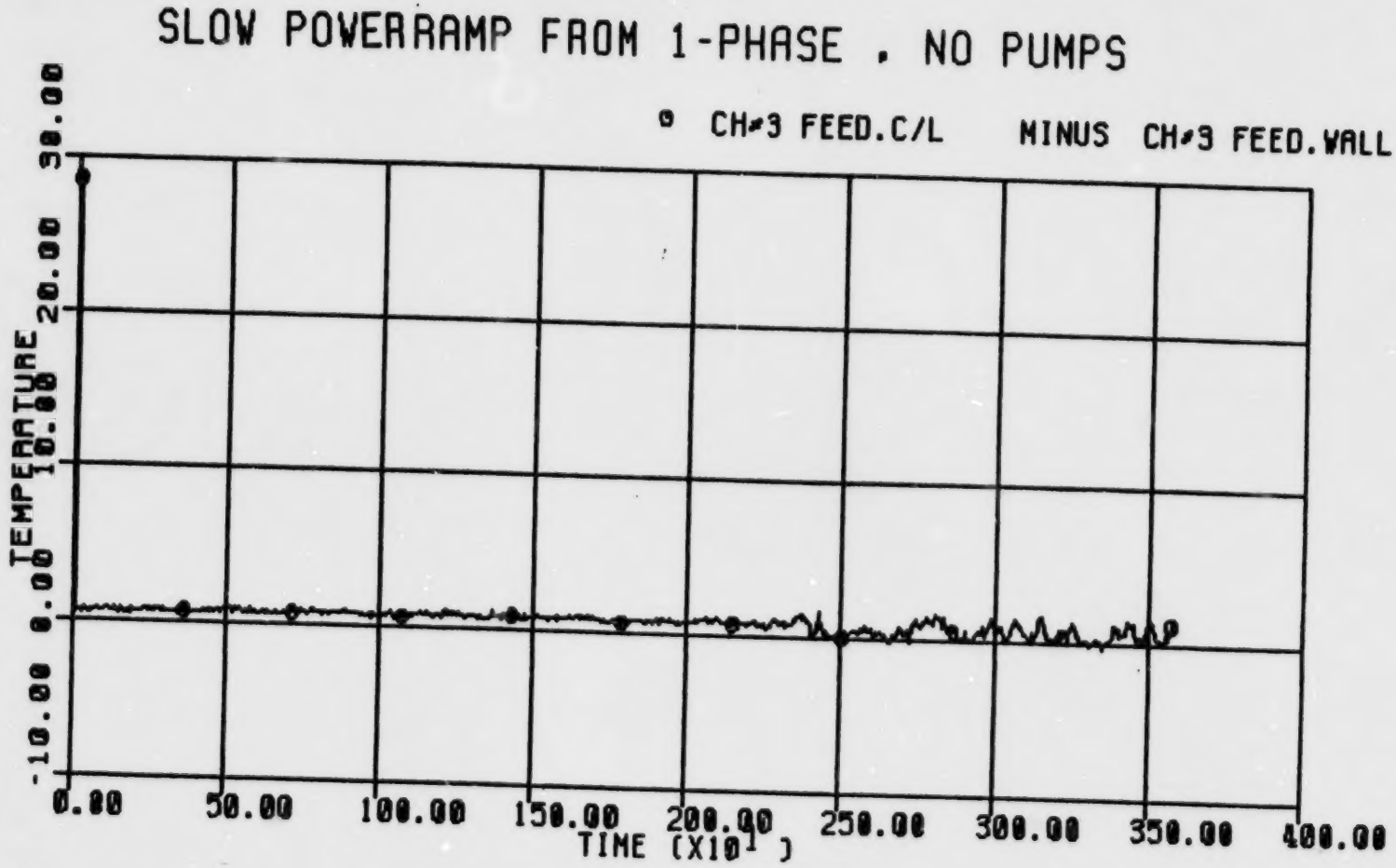

SLOW POWERRAMP FROM 1-PHASE , NO PUMPS
CH#3 FEED.C/L MINUS CH#3 FEED.WALL
TEMPERATURE
30.00
20.00
10.00
0.00
-10.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
TIME (X10¹)

FIGURE 3.2-8

(3) Under single phase conditions, a flow velocity of .063 m/s was measured in a feeder pipe using a stop watch. The pipes have a flow area of 5.07×10^{-4} m², and therefore the flow rate was

$$.063 \times 5.07 \times 10^{-4} \times 1000 = .032 \text{ kg/s}$$

This corresponds to a heated channel mass flux of

$$\frac{.032}{3.33 \times 10^{-4}} = 96 \text{ kg/s/m}^2$$

The velocity measurement was taken on the channel 2 outlet feeder. From figure 3.2-2, the temperature rise across the channel is about 20°C. From Figure 2-2, the channel mass flux calculated using the SOPHT model was 128 kg/s/m².

3.3 Standing Start Test 1

The standing start test was done to establish whether the flow pattern in the rig under two phase conditions depends upon the procedure and rig power used to establish the boiling conditions. The following procedure was used for the test:

(1) The system was heated to about 85°C with the pumps running.

(2) The power was shut off, with the pumps running to allow temperatures to equilibrate around the loop. With no temperature gradients in the system, there was no preferential flow direction, thus providing a true "standing start" condition.

(3) Once temperatures were stabilized in the system, power was raised to about 3 kW, and the pumps were shut off.

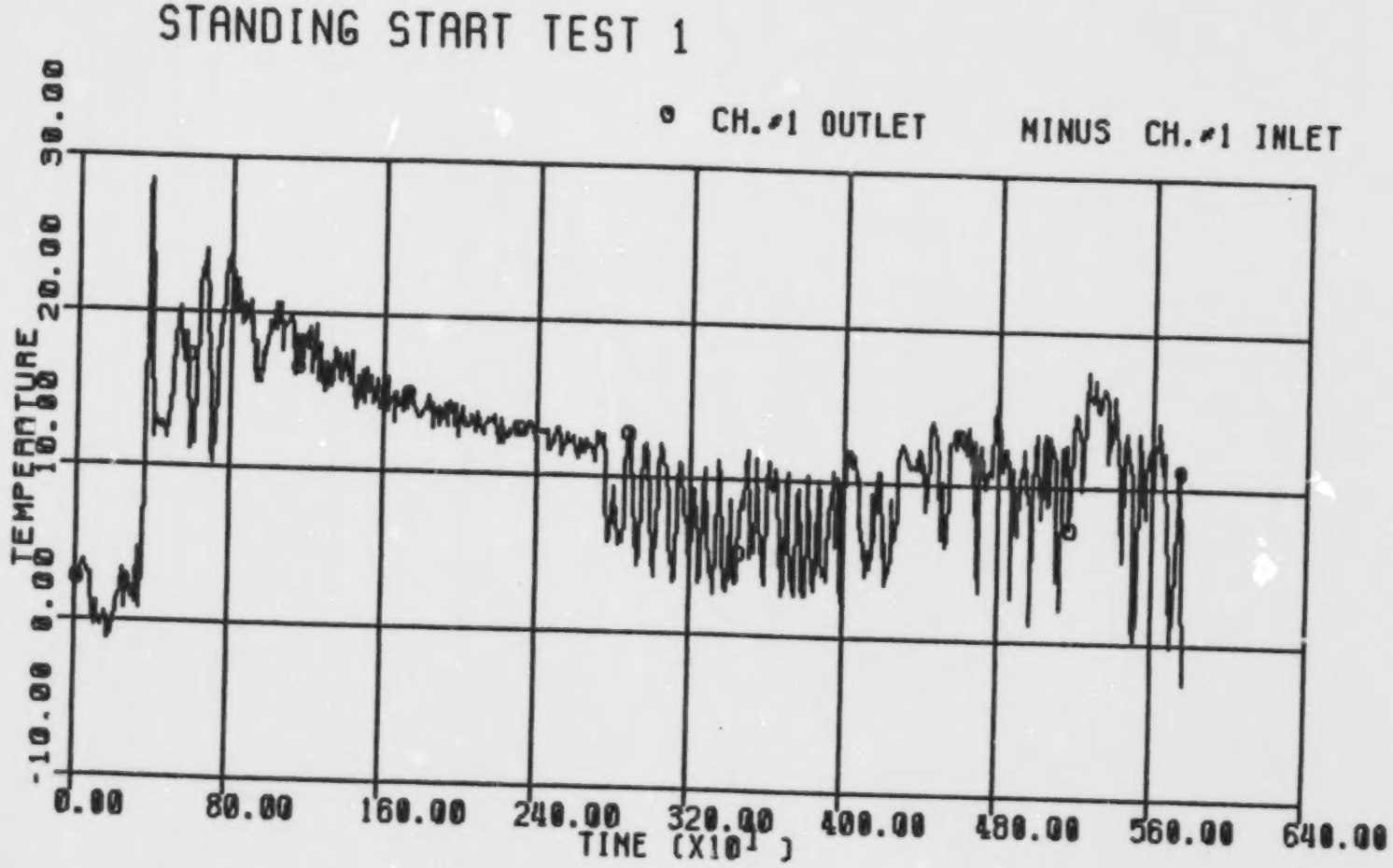

STANDING START TEST 1
CH.#1 OUTLET MINUS CH.#1 INLET
TEMPERATURE
30.00
20.00
10.00
0.00
-10.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10¹)

FIGURE 3.3-1

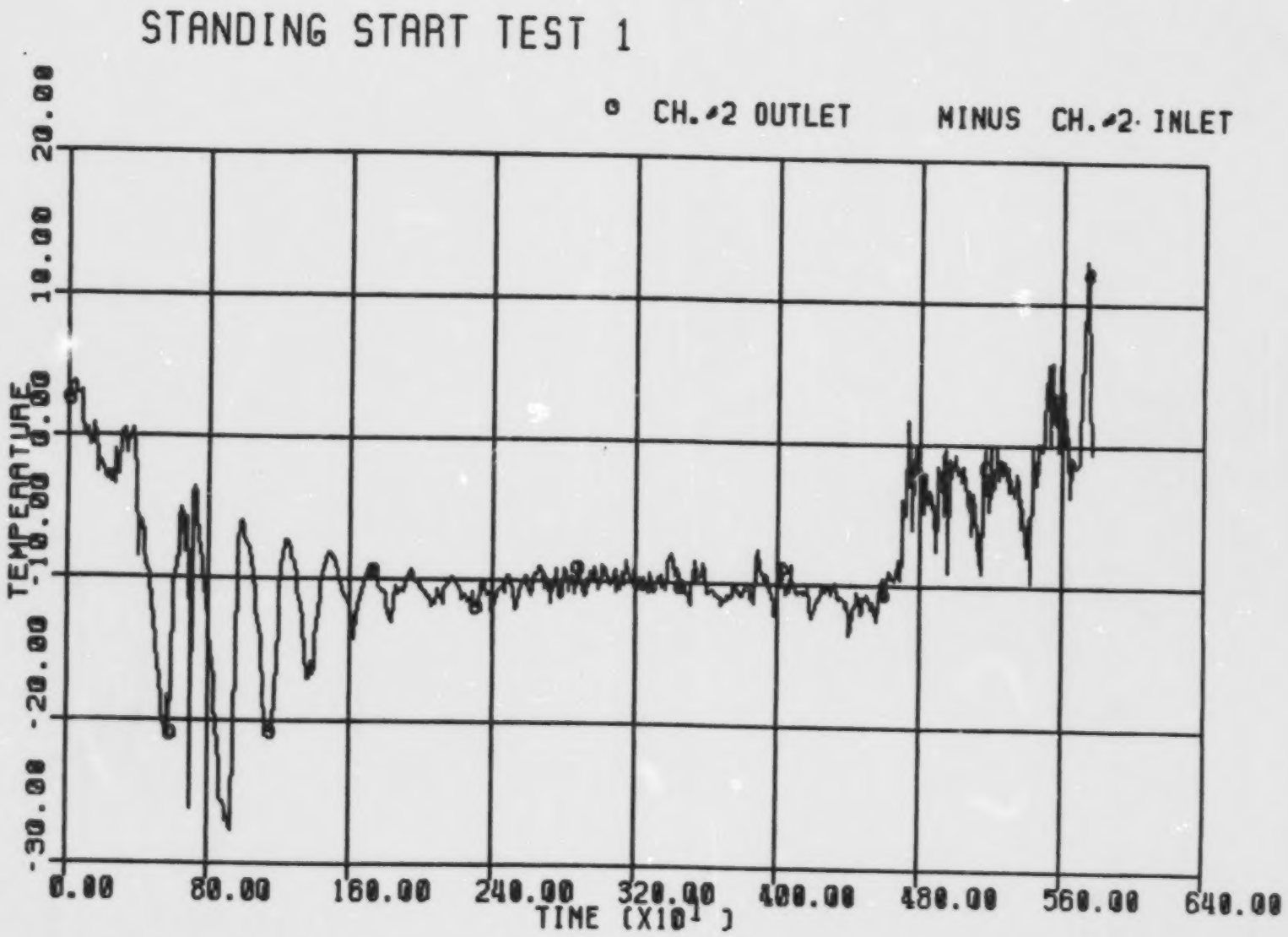

STANDING START TEST 1
CH.#2 OUTLET MINUS CH.#2 INLET
TEMPERATURE
20.00
10.00
0.00
-10.00
-20.00
-30.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10¹)

FIGURE 3.3-2

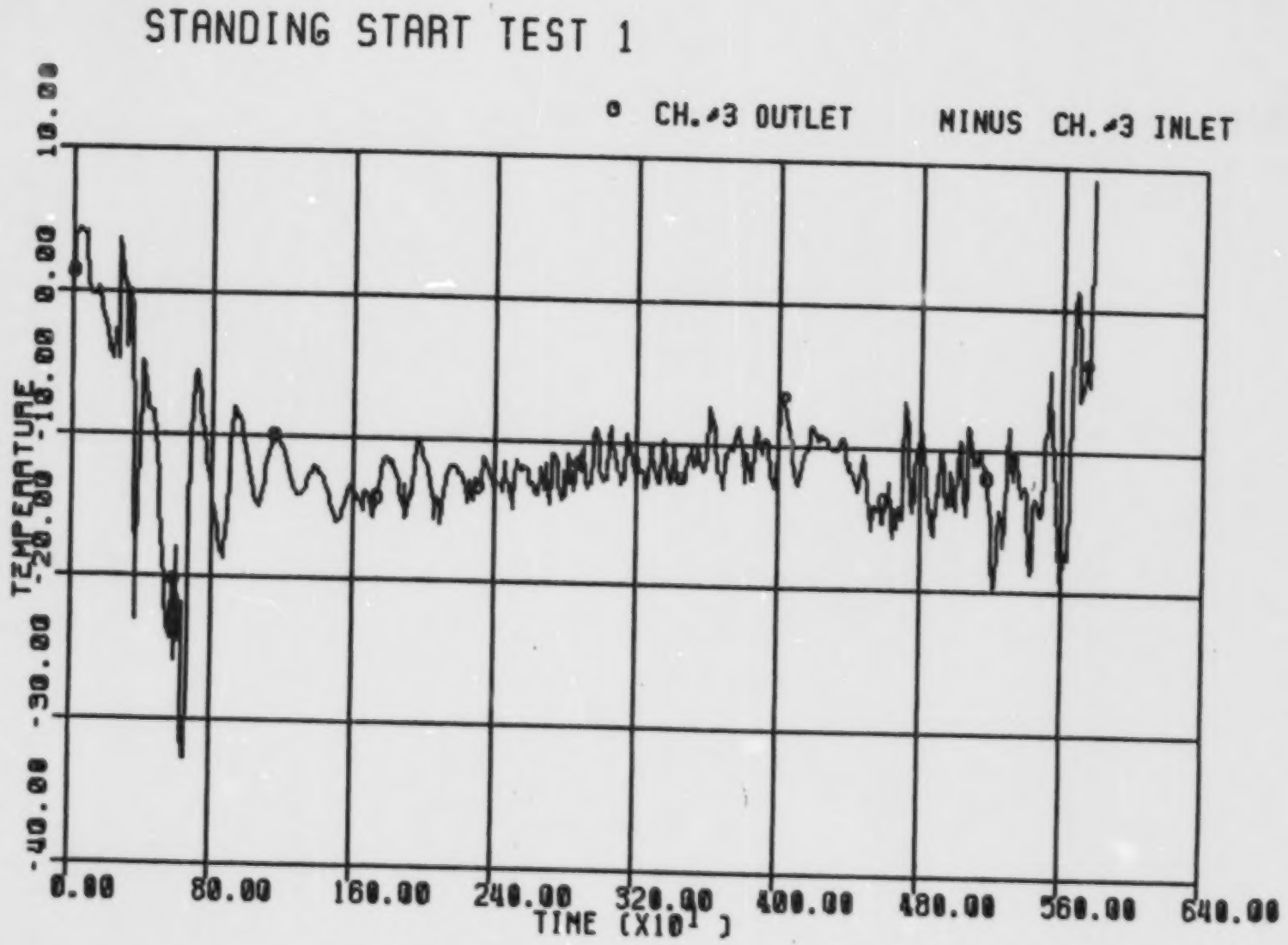

STANDING START TEST 1
CH.#3 OUTLET MINUS CH.#3 INLET
TEMPERATURE
10.00
0.00
-10.00
-20.00
-30.00
-40.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10¹)

FIGURE 3.3-3

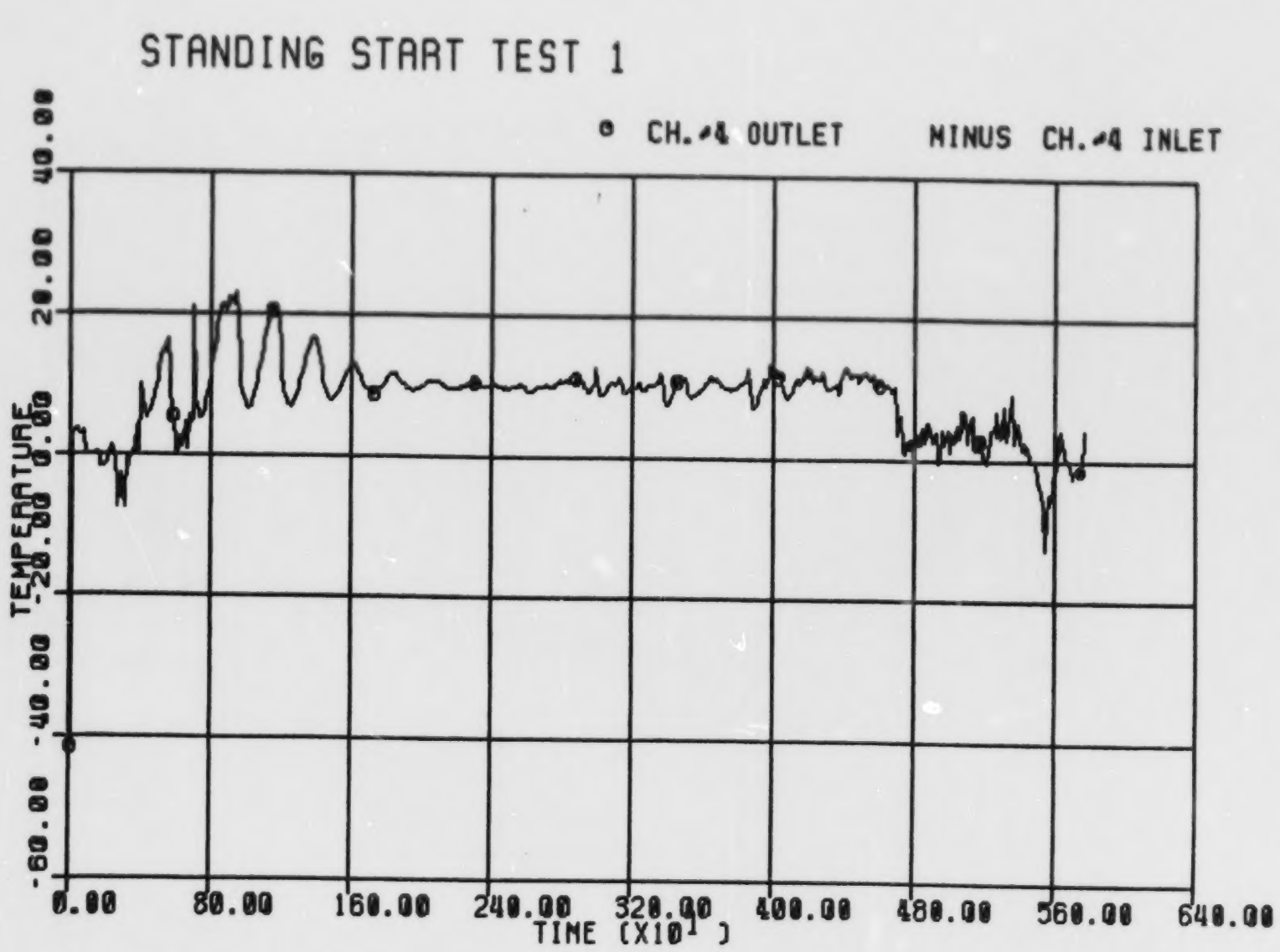

STANDING START TEST 1
CH.#4 OUTLET MINUS CH.#4 INLET
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
-60.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10¹)

FIGURE 3.3-4

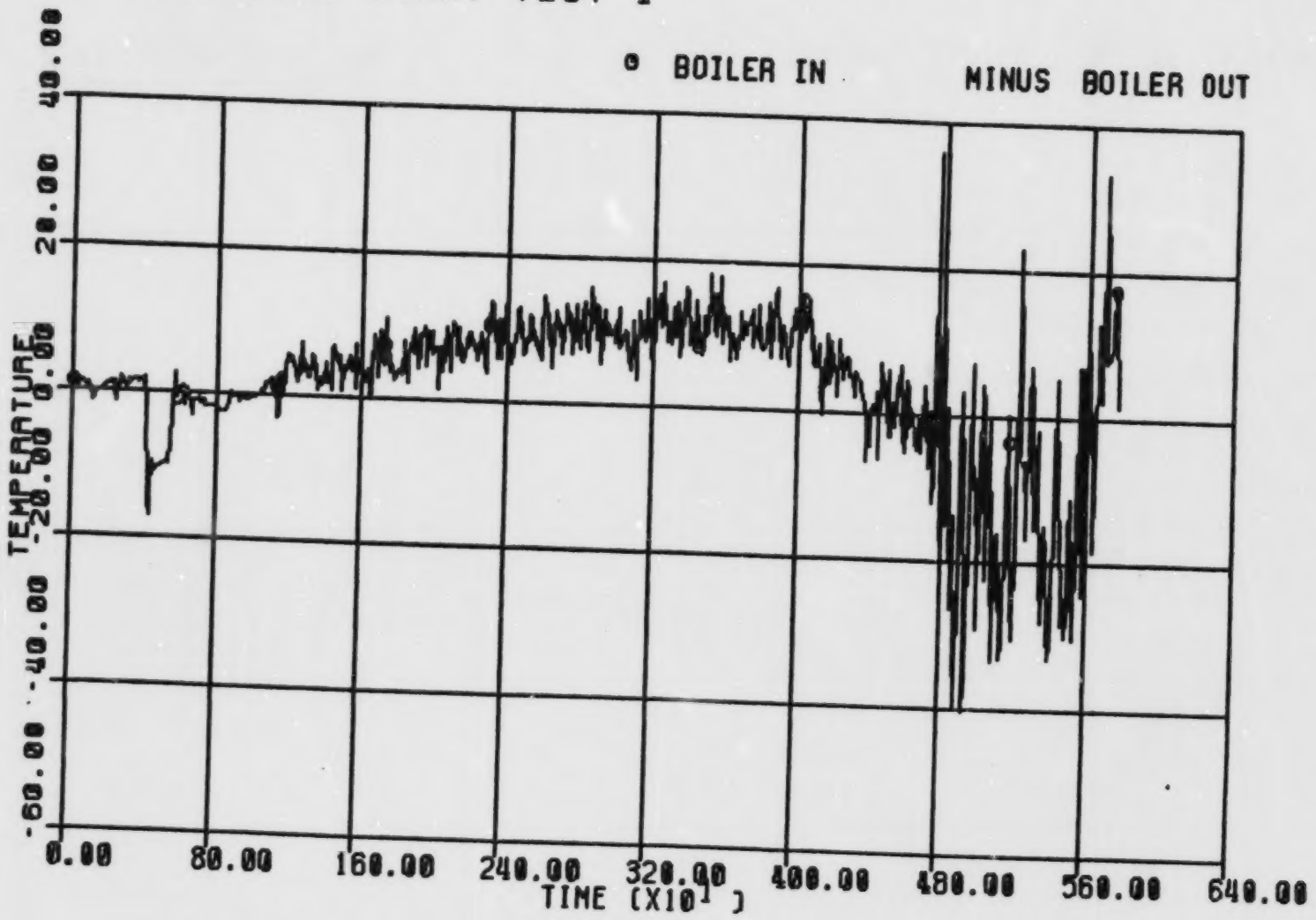

STANDING START TEST 1
BOILER IN
MINUS BOILER OUT
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
-60.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10)

FIGURE 3.3-5

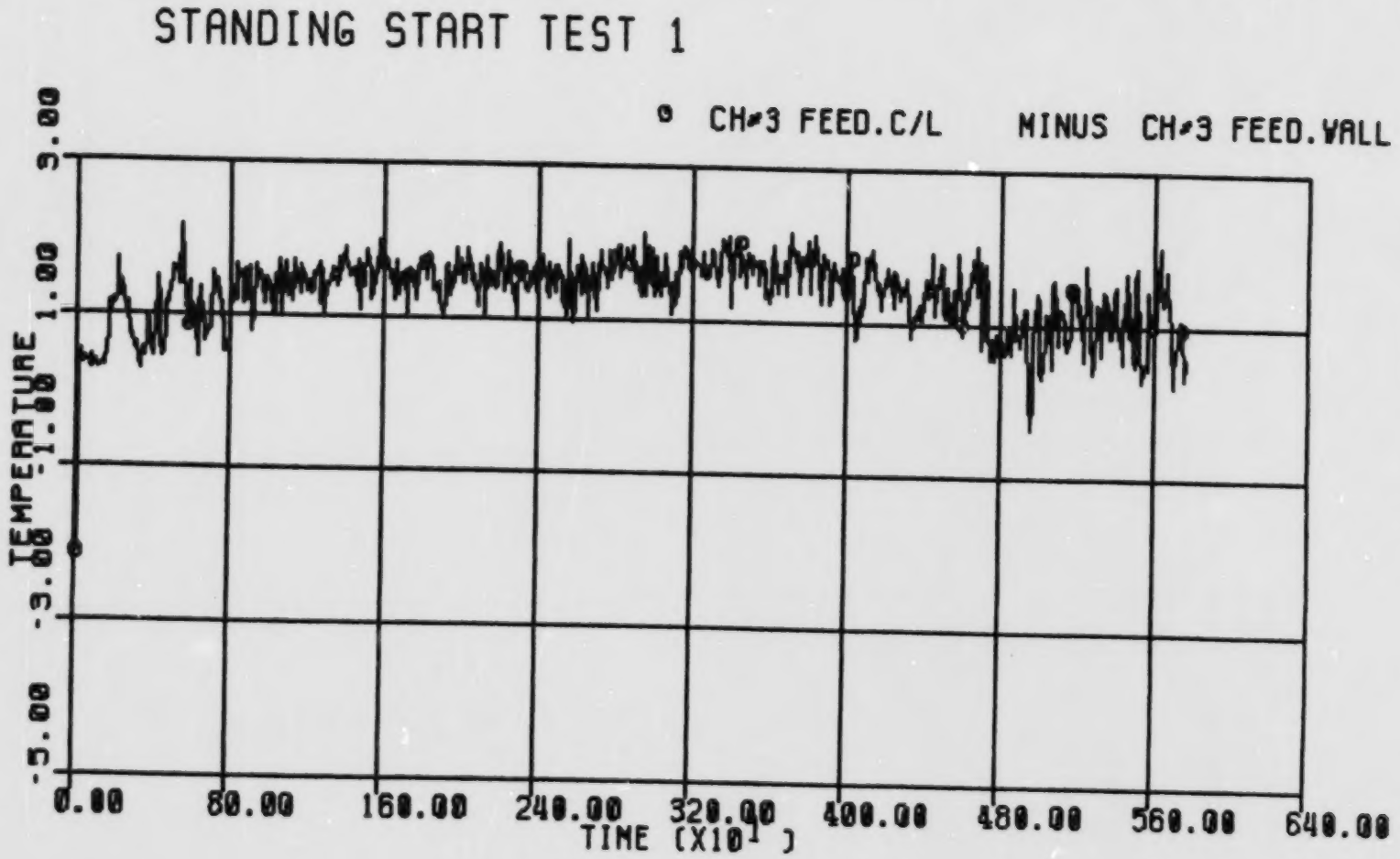

STANDING START TEST 1
CH#3 FEED.C/L MINUS CH#3 FEED.WALL
TEMPERATURE
3.00
1.00
-1.00
-3.00
-5.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10¹)

FIGURE 3.3-6

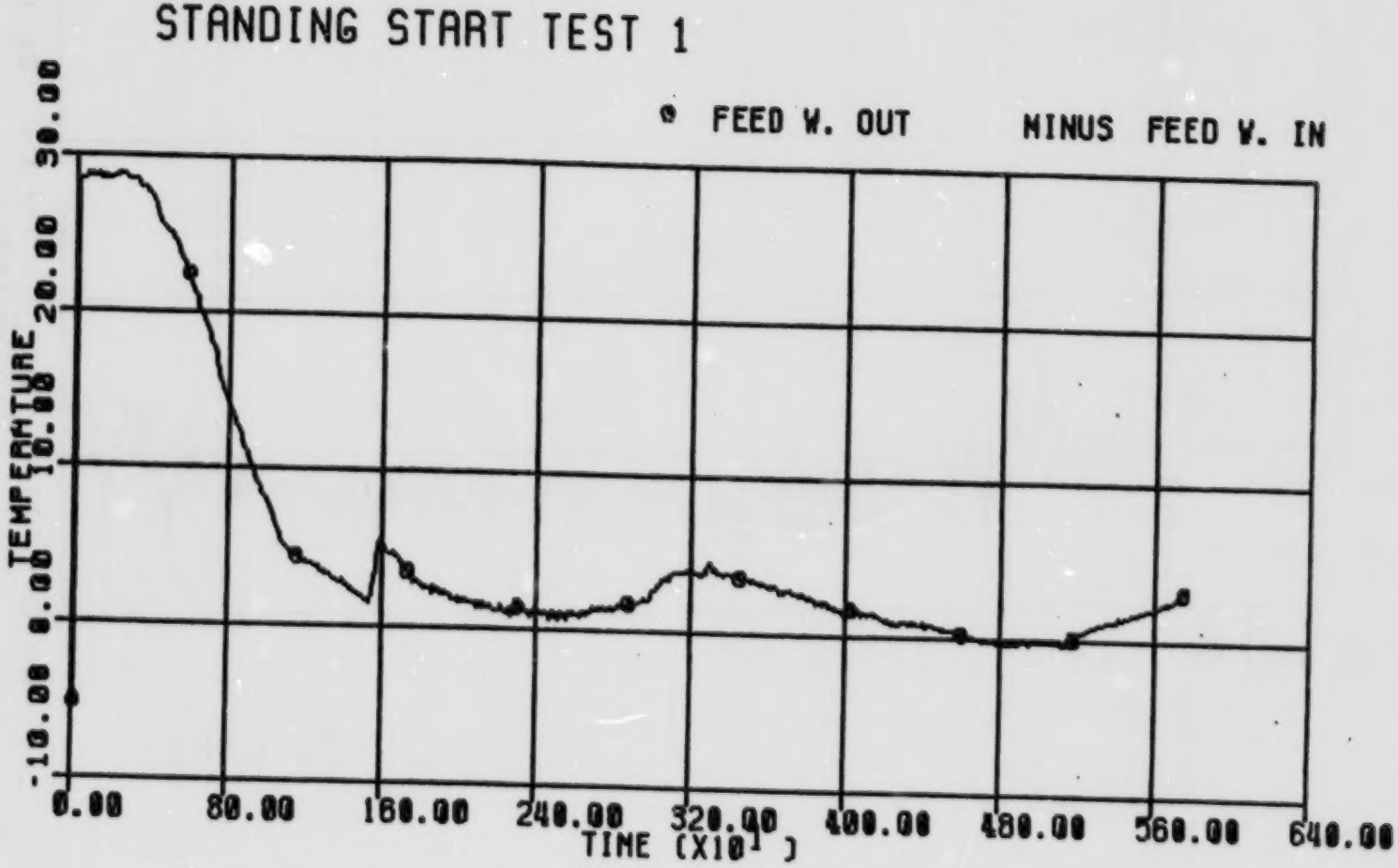

STANDING START TEST 1
FEED W. OUT
MINUS FEED W. IN
TEMPERATURE
30.00
20.00
10.00
0.00
-10.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10)

FIGURE 3.3-7

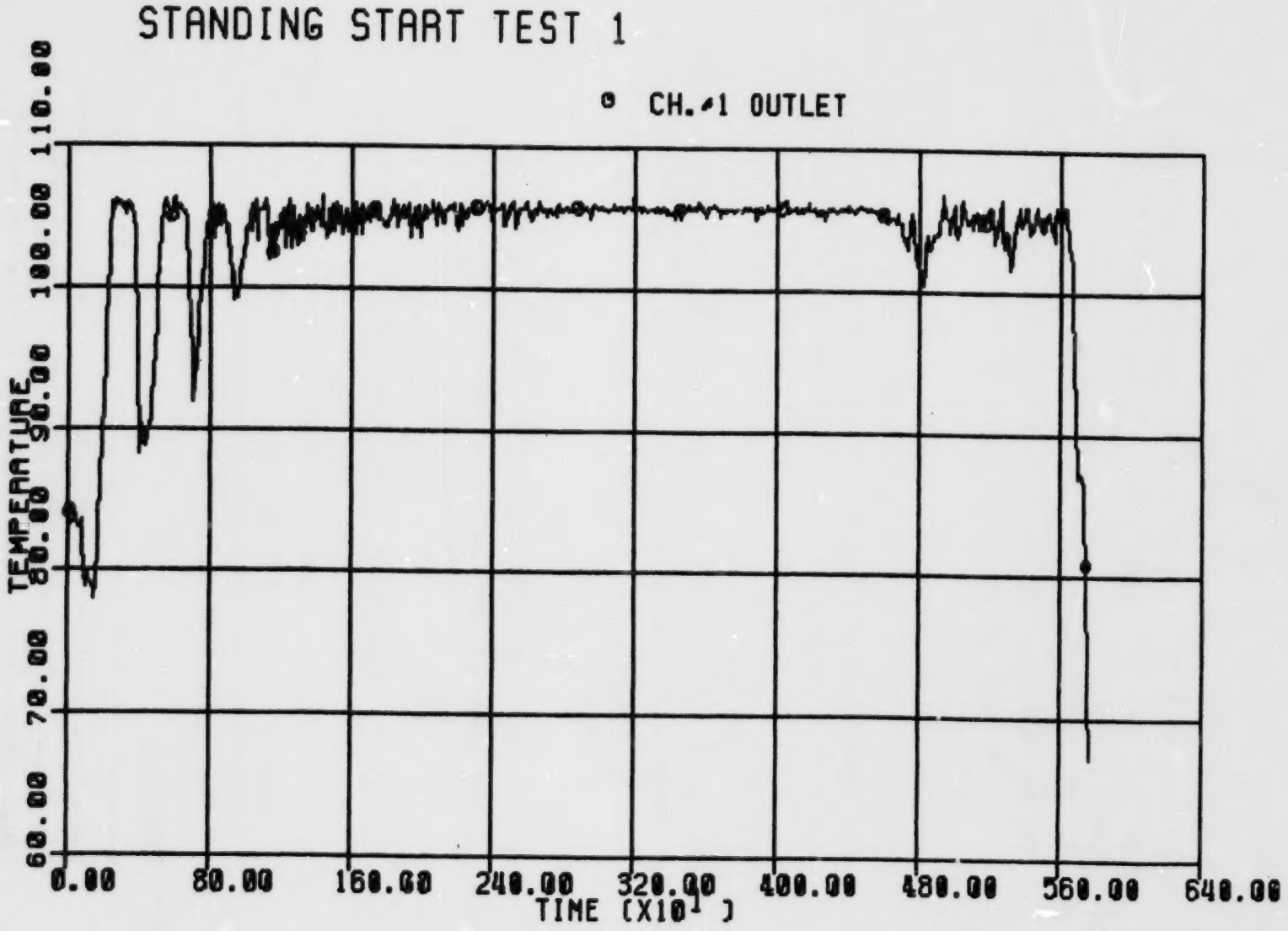

STANDING START TEST 1
CH. #1 OUTLET
TEMPERATURE
60.00
70.00
80.00
90.00
100.00
110.00
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
TIME (X10¹)

FIGURE 3.3-8

Figures 3.3-1 to 3.3-8 show temperature differences in the rig during the test. The following observations were made:

(1) Boiling began in the heated channels immediately after shutting down the pumps and raising power.

(2) The two phase channel flow distribution seen in the power ramp test was established. Channels 1 and 4 had forward flow and channels 2 and 3 had reverse flow. The temperature differences shown in figures 3.3-1 to 3.3-4 indicate the flow pattern.

(3) As in the previous test, very little flow goes through the boilers as shown in figure 3.3-5. The low primary flow through the boilers results in low boiler power as shown in figure 3.3-7.

(4) It should be noted that before starting this test the loop had been partially drained and re-filled. There appeared to be some air at the top of the U-tubes in the boilers, and thus air could have prevented a steady single phase thermosyphoning flow from developing. At the low power used for the test, a single phase thermosyphoning flow should have been a possible outcome. The boiling condition at low power was due either to the initial "standing start" conditions, or the presence of air in the boiler U-tubes.

3.4 Pump Trip

The pump trip test was done in the same way as the single phase test described in section 3.1. However, rig power was set at 6.7 kW before the pump was tripped. With coolant temperature at 81°C (figure 3.4-8), the heater power of 6.7 kW is sufficient to cause boiling after a pump trip. This test provides another approach to the boiling conditions for establishing consistency of the two phase flow patterns.

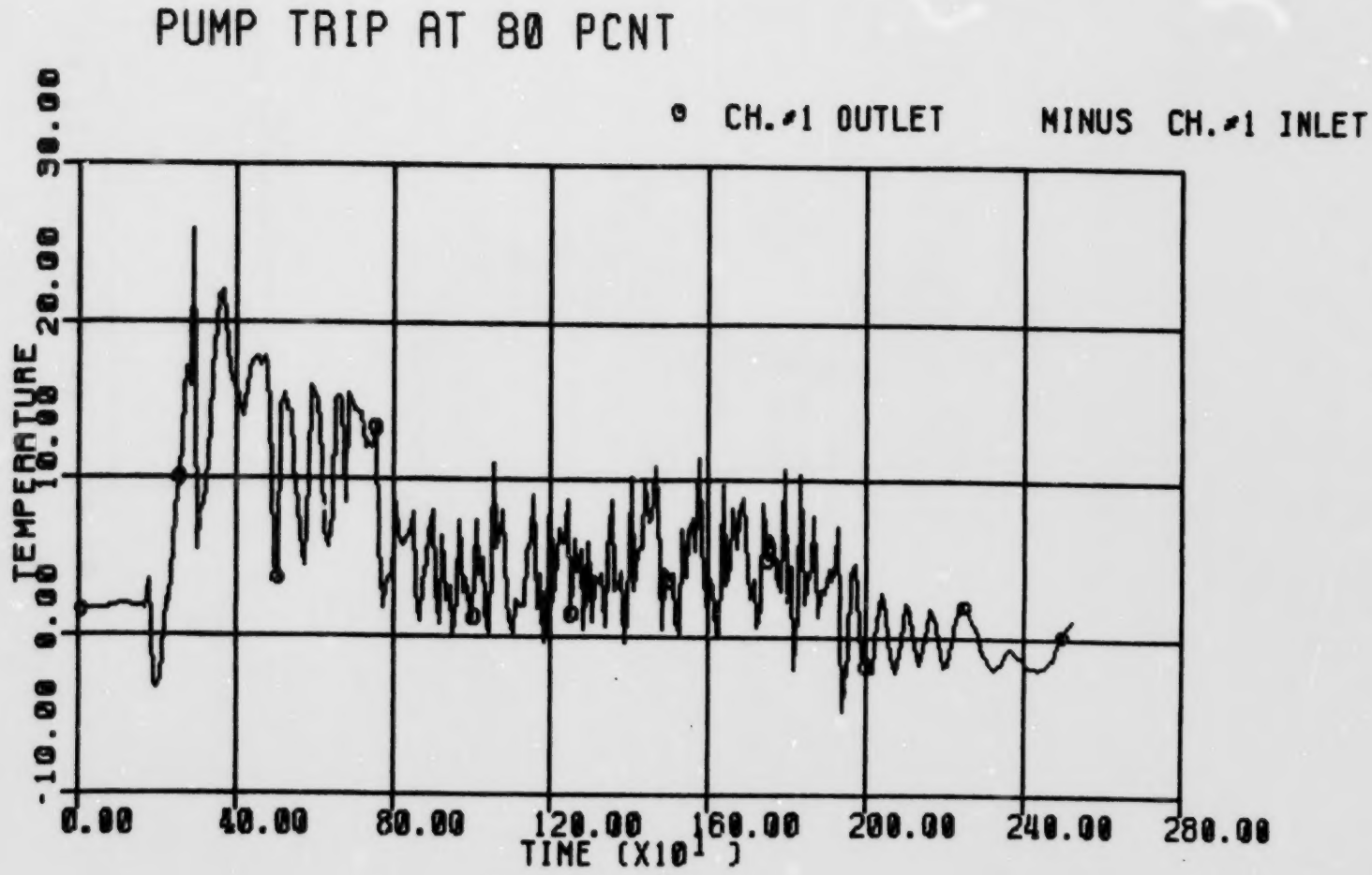

PUMP TRIP AT 80 PCNT
CH.#1 OUTLET MINUS CH.#1 INLET
TEMPERATURE
30.00
20.00
10.00
0.00
-10.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-1

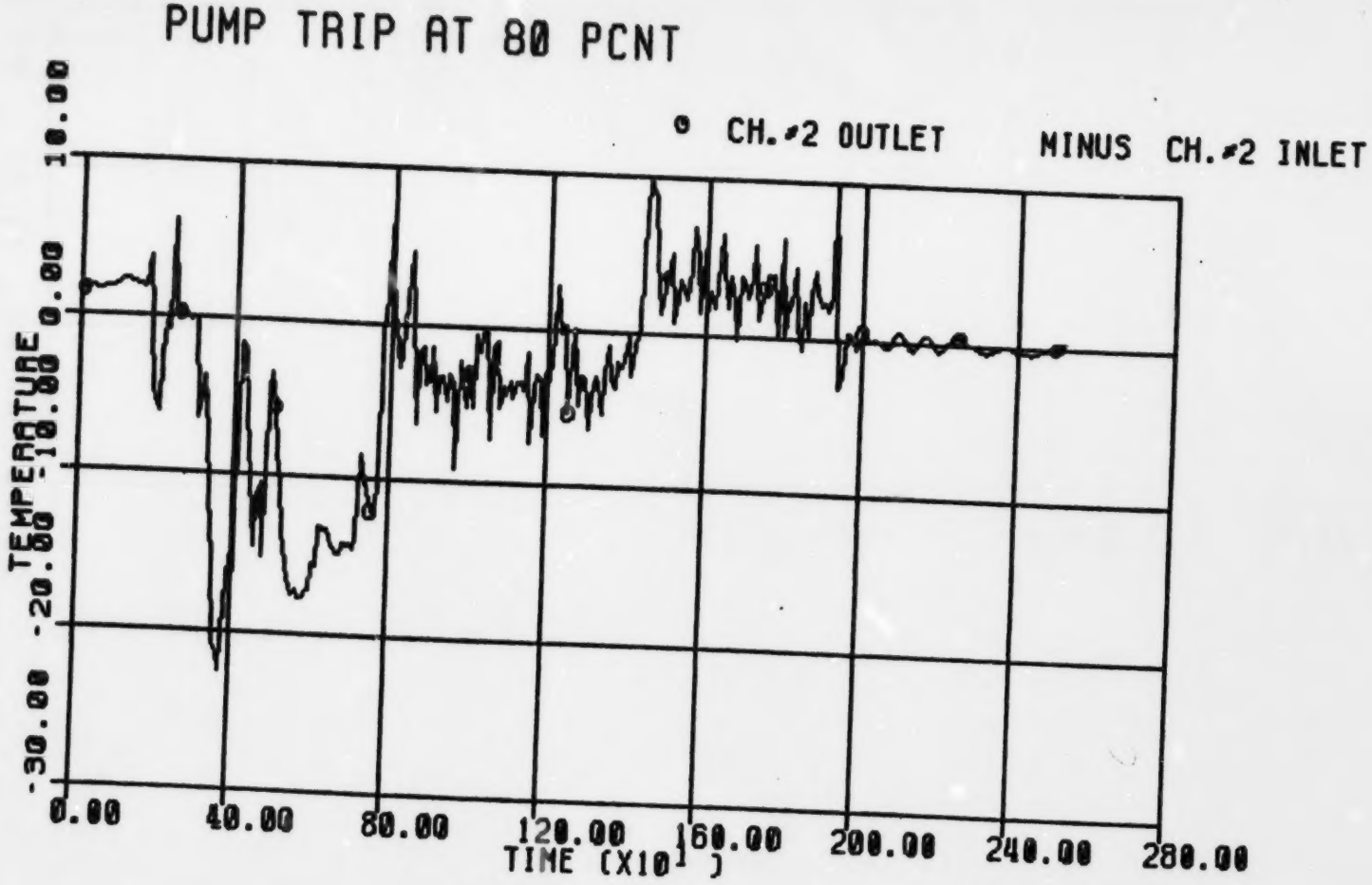

PUMP TRIP AT 80 PCNT
CH.#2 OUTLET MINUS CH.#2 INLET
TEMPERATURE
10.00
0.00
-10.00
-20.00
-30.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-2

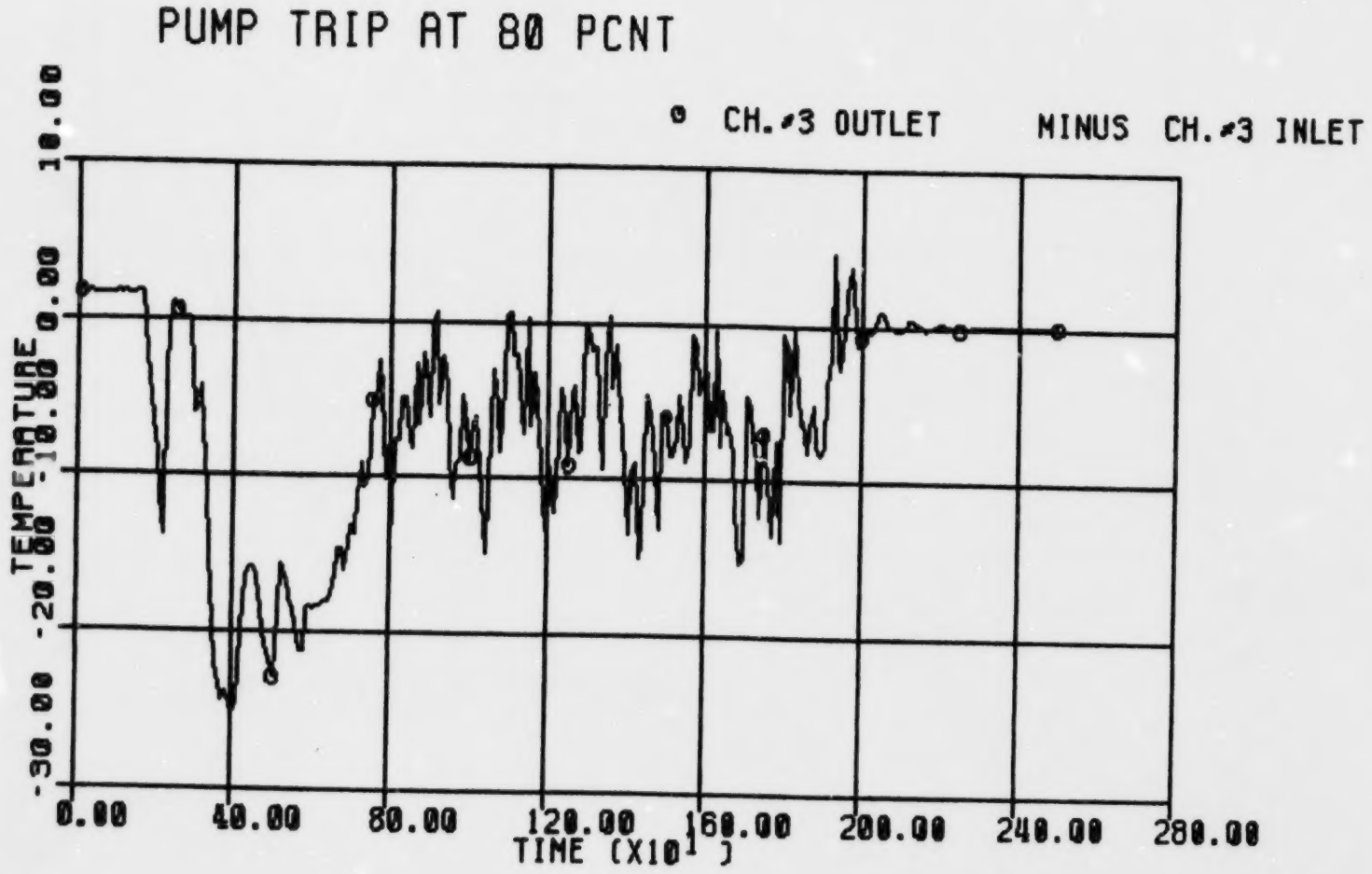

PUMP TRIP AT 80 PCNT
CH.#3 OUTLET MINUS CH.#3 INLET
TEMPERATURE
10.00
0.00
-10.00
-20.00
-30.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-3

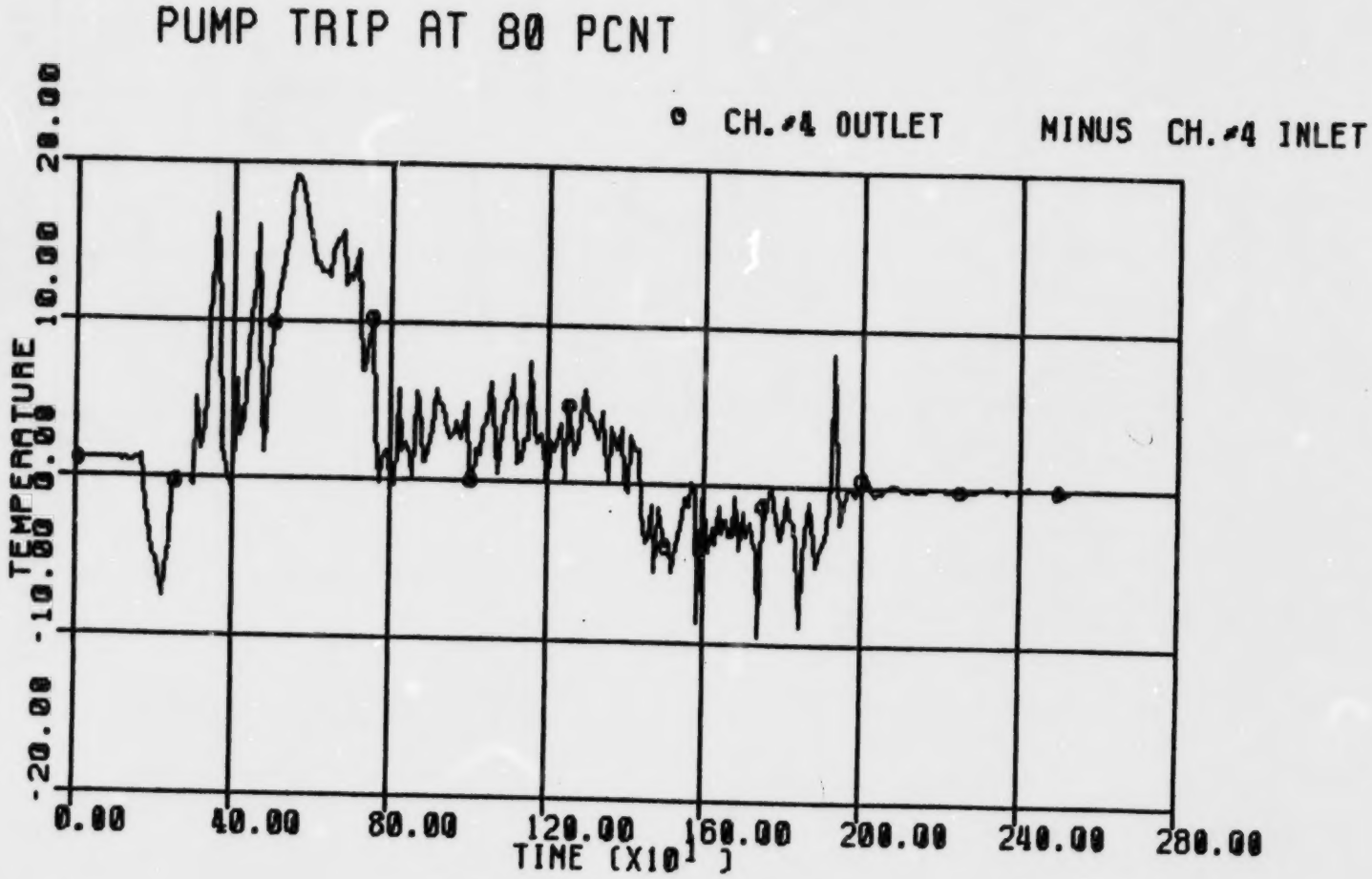

PUMP TRIP AT 80 PCNT
CH.#4 OUTLET MINUS CH.#4 INLET
TEMPERATURE
20.00
10.00
0.00
-10.00
-20.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-4

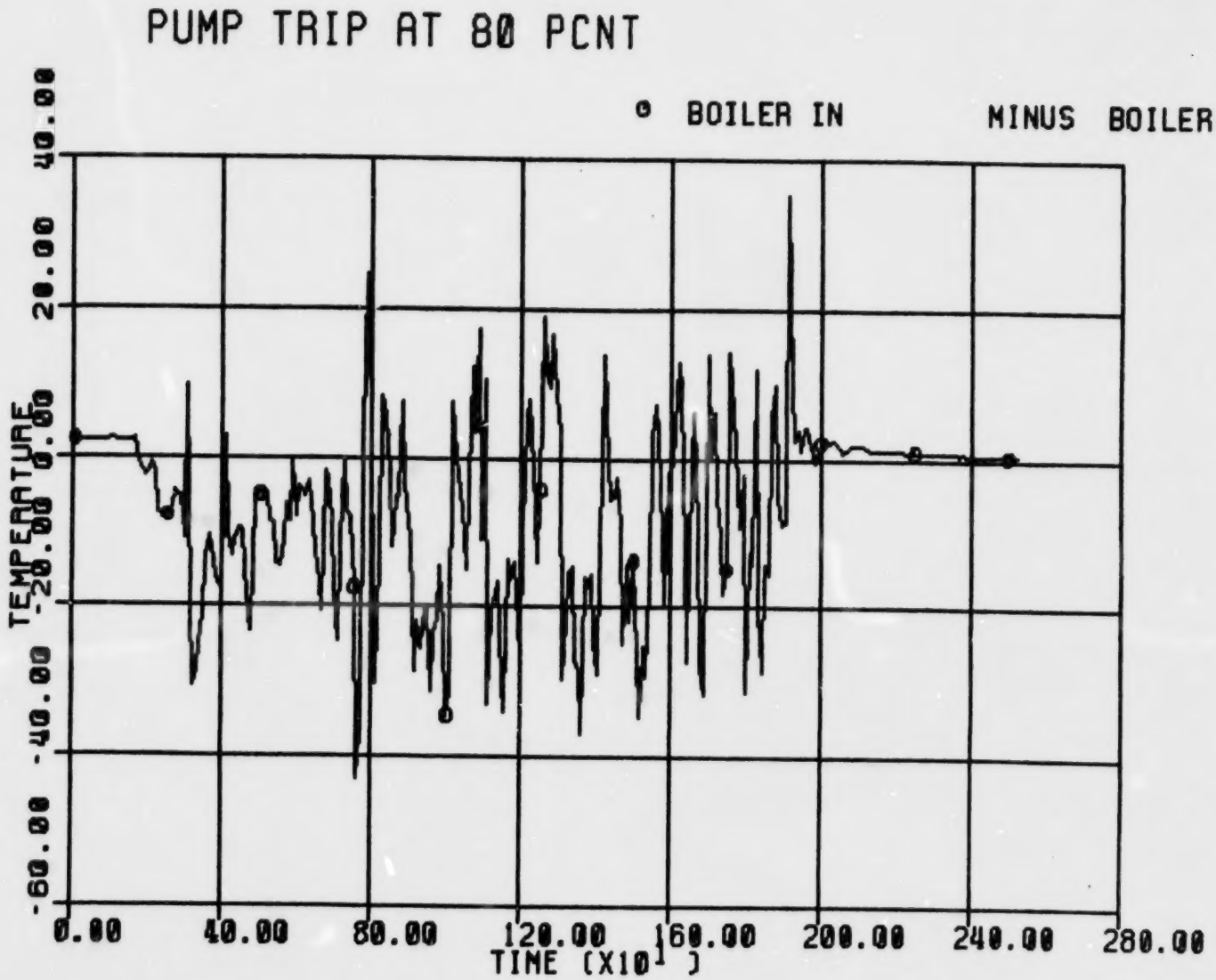

PUMP TRIP AT 80 PCNT
BOILER IN
MINUS BOILER OUT
TEMPERATURE
40.00
20.00
0.00
-20.00
-40.00
-60.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-5

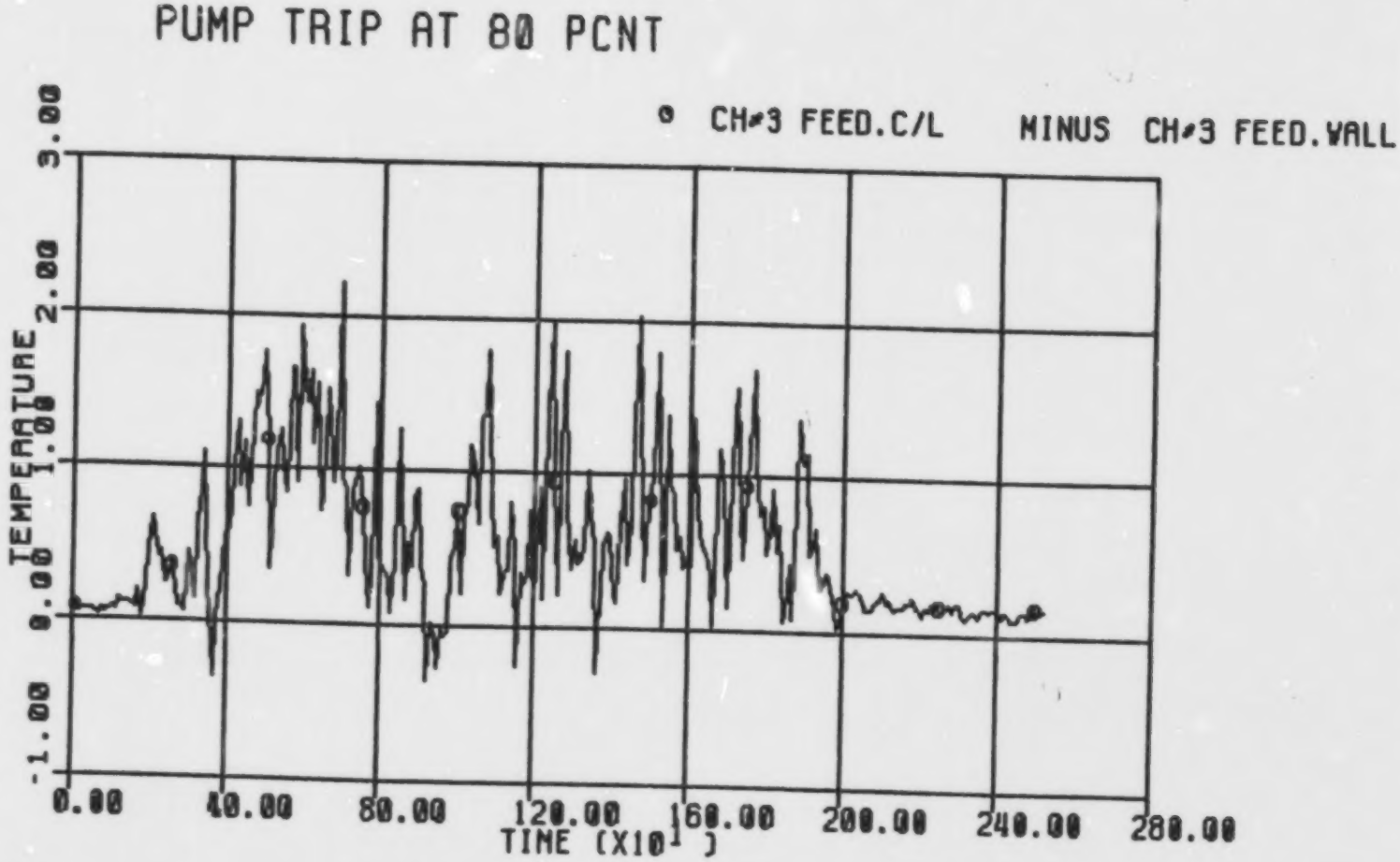

PUMP TRIP AT 80 PCNT
CH#3 FEED.C/L
MINUS CH#3 FEED.WALL
TEMPERATURE
3.00
2.00
1.00
0.00
-1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10¹)

FIGURE 3.4-6

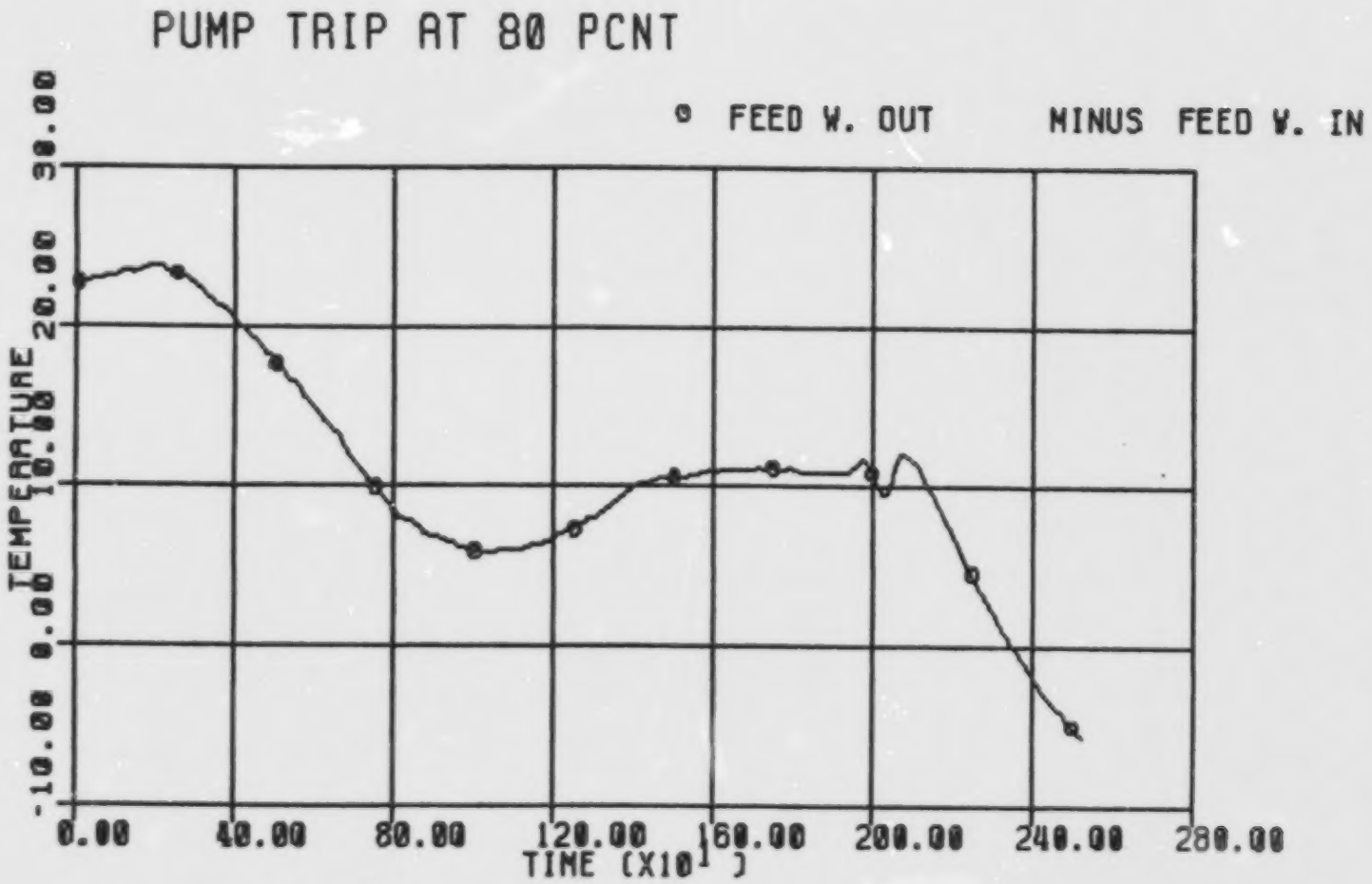

PUMP TRIP AT 80 PCNT
FEED W. OUT
MINUS FEED W. IN
TEMPERATURE
-10.00
0.00
10.00
20.00
30.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-7

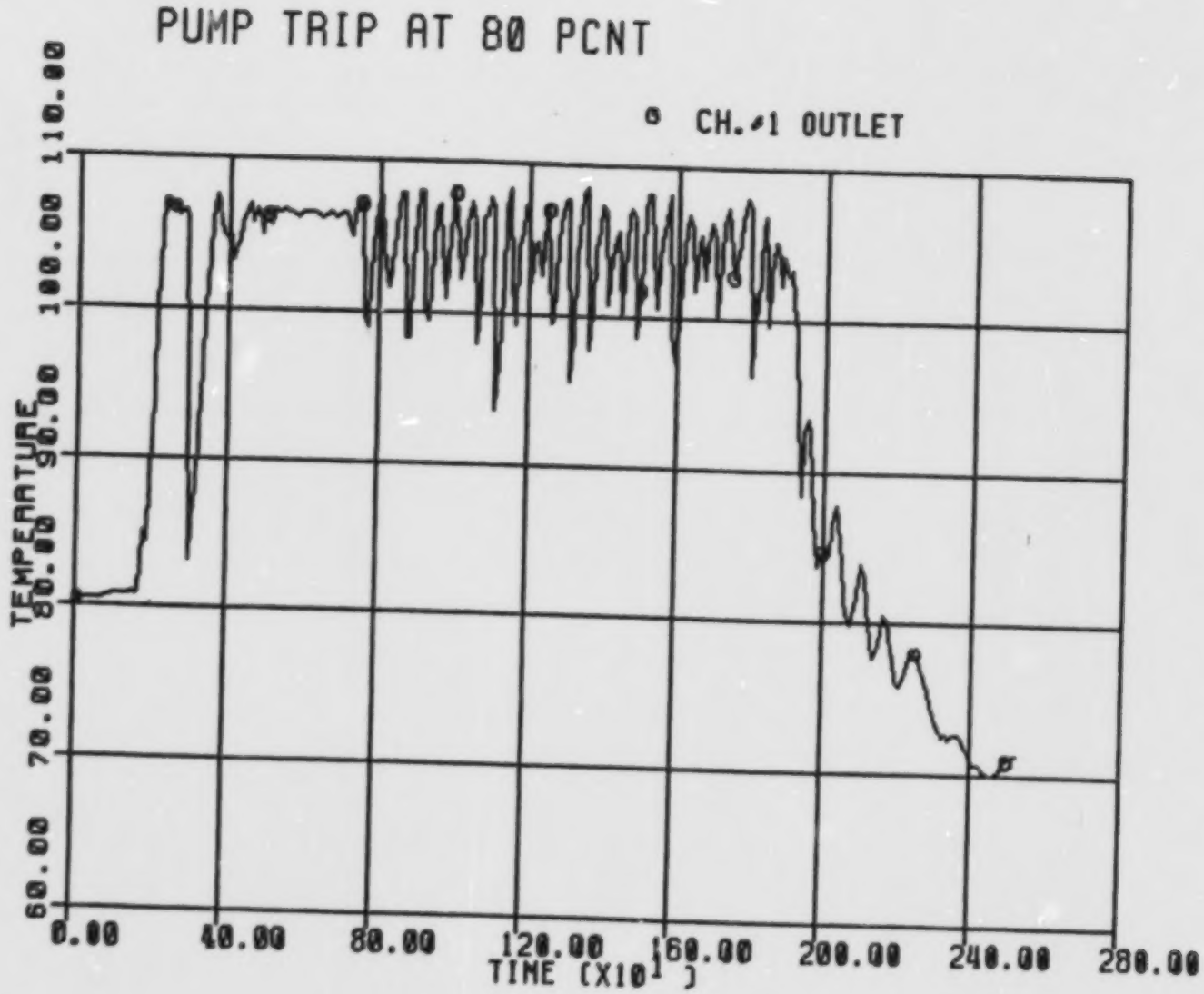

PUMP TRIP AT 80 PCNT
CH. #1 OUTLET
TEMPERATURE
60.00
70.00
80.00
90.00
100.00
110.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-8

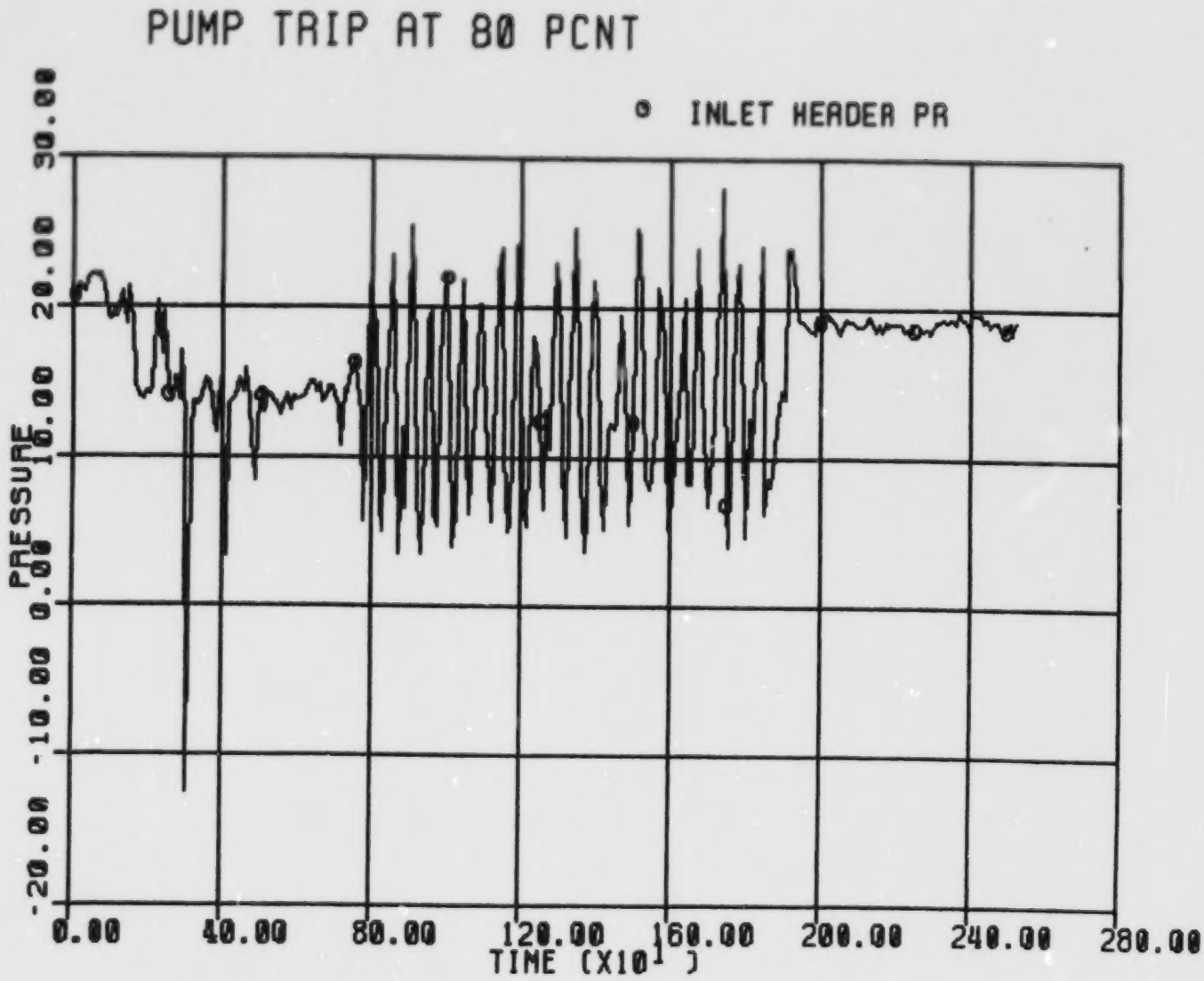

PUMP TRIP AT 80 PCNT
INLET HEADER PR
PRESSURE
30.00
20.00
10.00
0.00
-10.00
-20.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-9

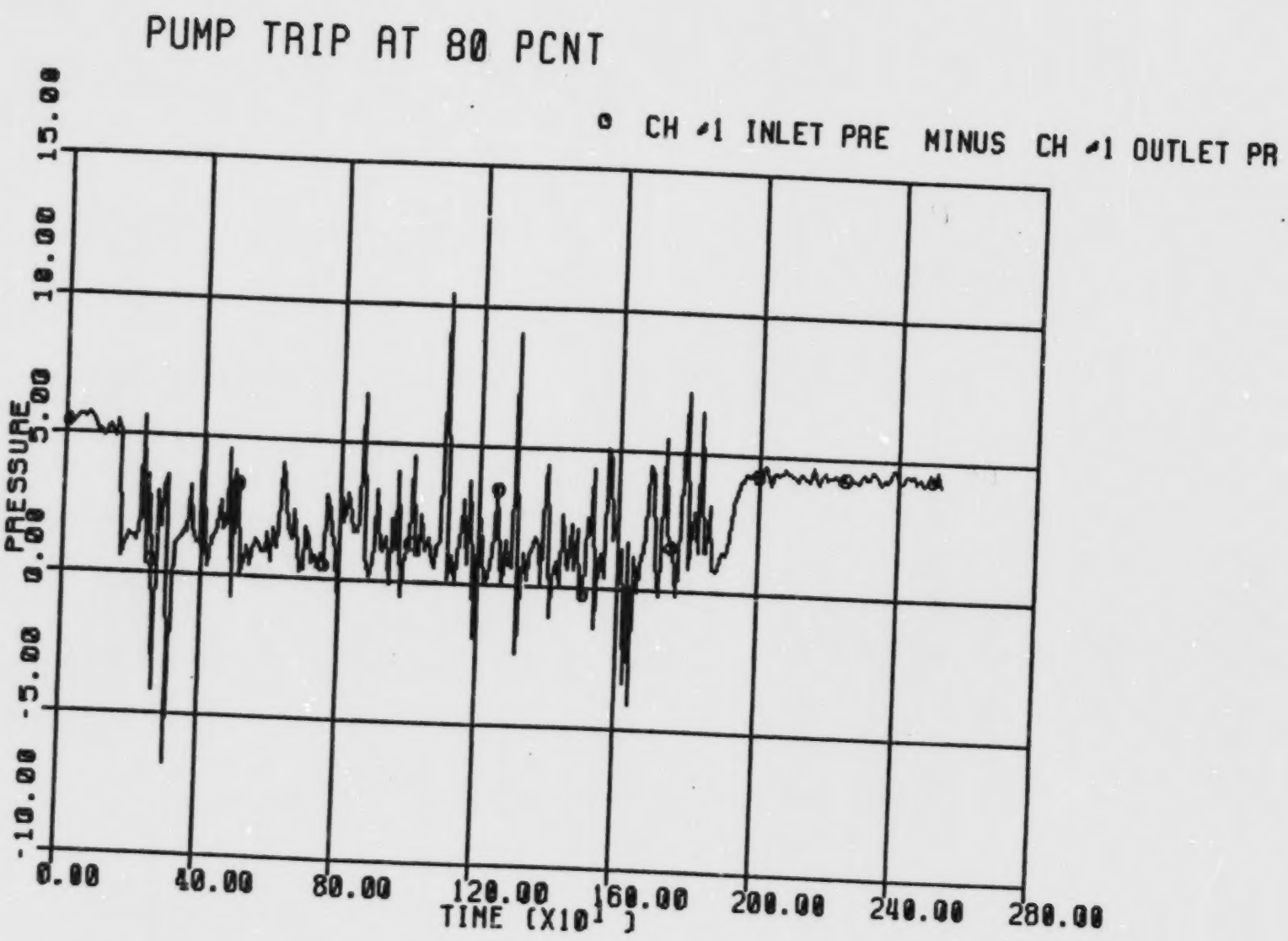

PUMP TRIP AT 80 PCNT
CH #1 INLET PRE MINUS CH #1 OUTLET PR
PRESSURE
15.00
10.00
5.00
0.00
-5.00
-10.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-10

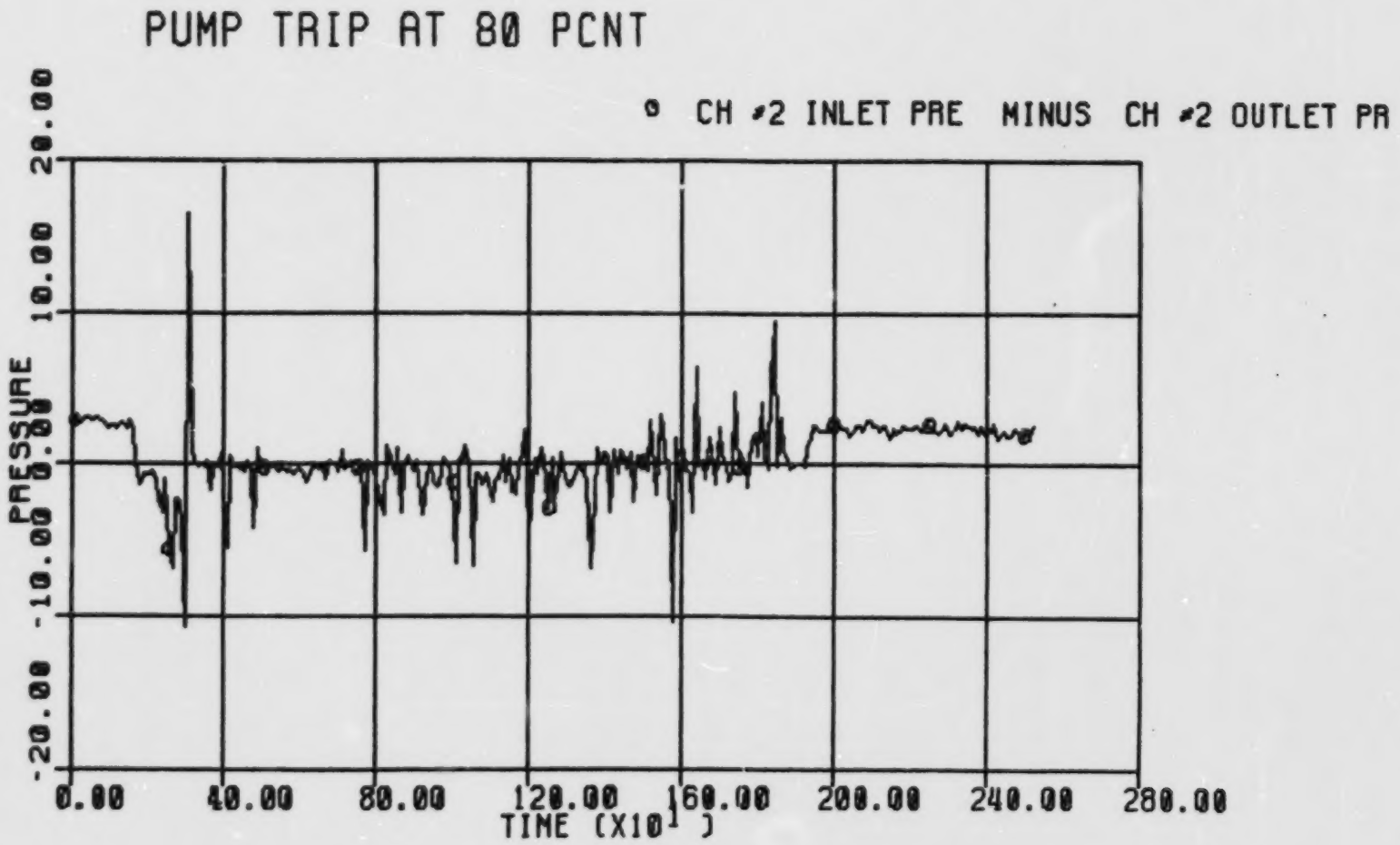

PUMP TRIP AT 80 PCNT
CH #2 INLET PRE MINUS CH #2 OUTLET PR
PRESSURE
20.00
10.00
0.00
-10.00
-20.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
TIME (X10)

FIGURE 3.4-11

Figures 3.4-1 to 3.4-8 show system temperature response. Figures 3.4-9 to 3.4-11 show pressures. The pumps were tripped at 200s, and boiling in the heated channels began immediately as shown in figures 3.4-1 to 3.4-4. The flow pattern seen before developed immediately with channels 1 and 4 having forward flow and channels 2 and 3 with negative flow. Flow oscillates in the boilers as shown by figure 3.4-5, and heat removed by the boilers drops after the pumps are tripped as shown in figure 3.4-7. At about 1400s into this test, the flows in channels 2 and 4 reversed, as shown in figures 3.4-2 and 3.4-4. This reversal indicates that two phase flow may occur in patterns other than that seen so far (1+, 2-, 3-, 4+). The observed flow pattering all show the same feature: within a pass, flows in the two channels are always opposite.

3.5 Standing Start Test 2

The second standing start experiment was done to study the effect of channel power on the final flow pattern. Also, air was eliminated from the loop for this test to ensure that a vapour lock would not occur in the steam generators. The rig was run at 6.2 kW for the test. Figures 3.5-1 to 3.5-12 show temperatures and pressures during the experiment. Power was shut off at 100s with the pumps running to allow the temperatures to equilibrate. At 300s, power was turned back on and the pumps were shut off. By 500s, the two phase flow pattern seen before was established, with forward flow in channels 1 and 4, reverse flow in channels 2 and 3.

The experiment was interrupted at 650s by a break in heated channel number 4. Figure 3.5-9 shows inlet header pressure. When the break occurred, pressure dropped rapidly from 13 kPa(g) to about -18 kPa(g). The rig power supply was shut off at this time, and pressure recovered to atmospheric.

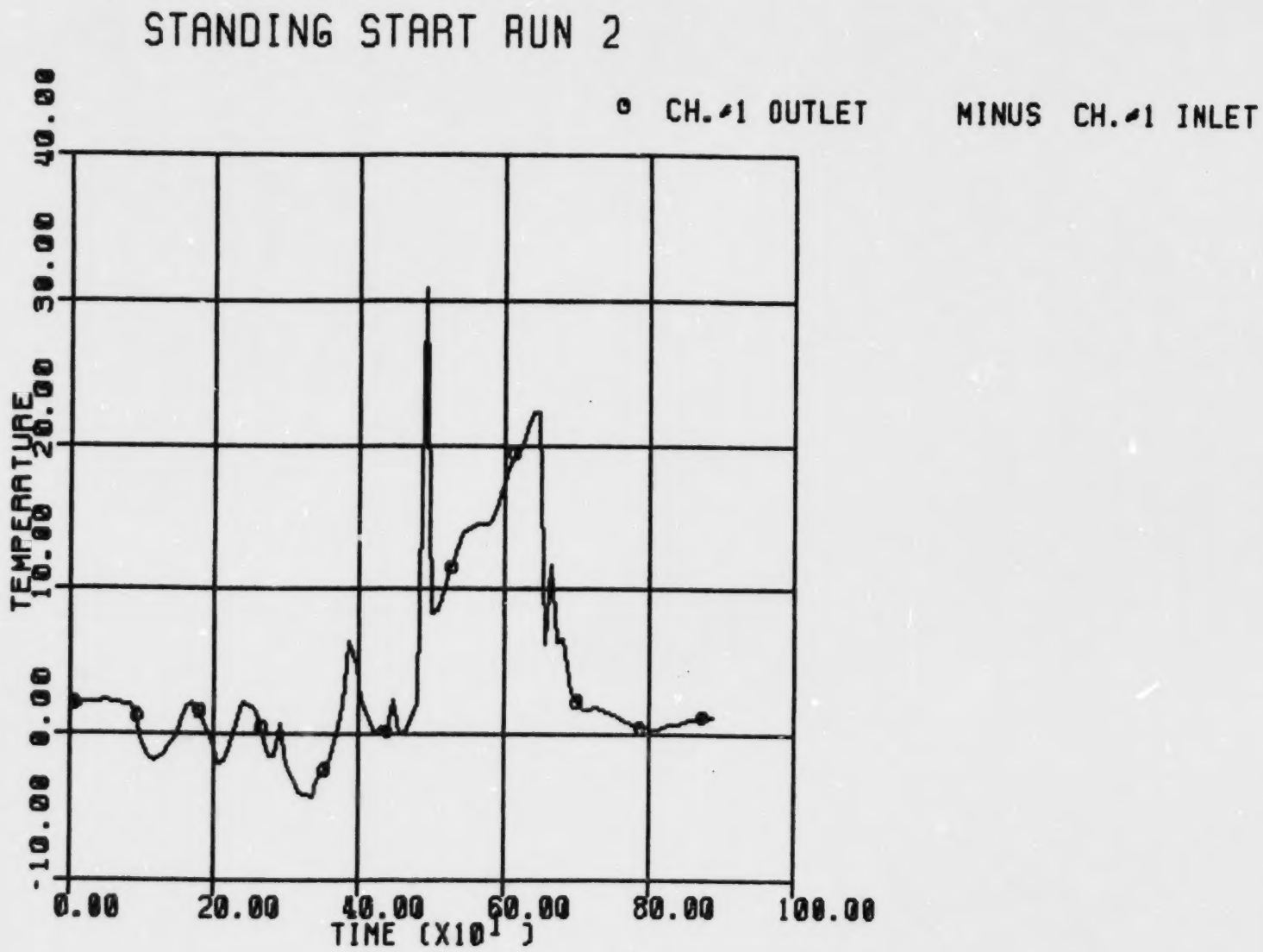

STANDING START RUN 2
o CH.#1 OUTLET MINUS CH.#1 INLET
TEMPERATURE
40.00
30.00
20.00
10.00
0.00
-10.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-1

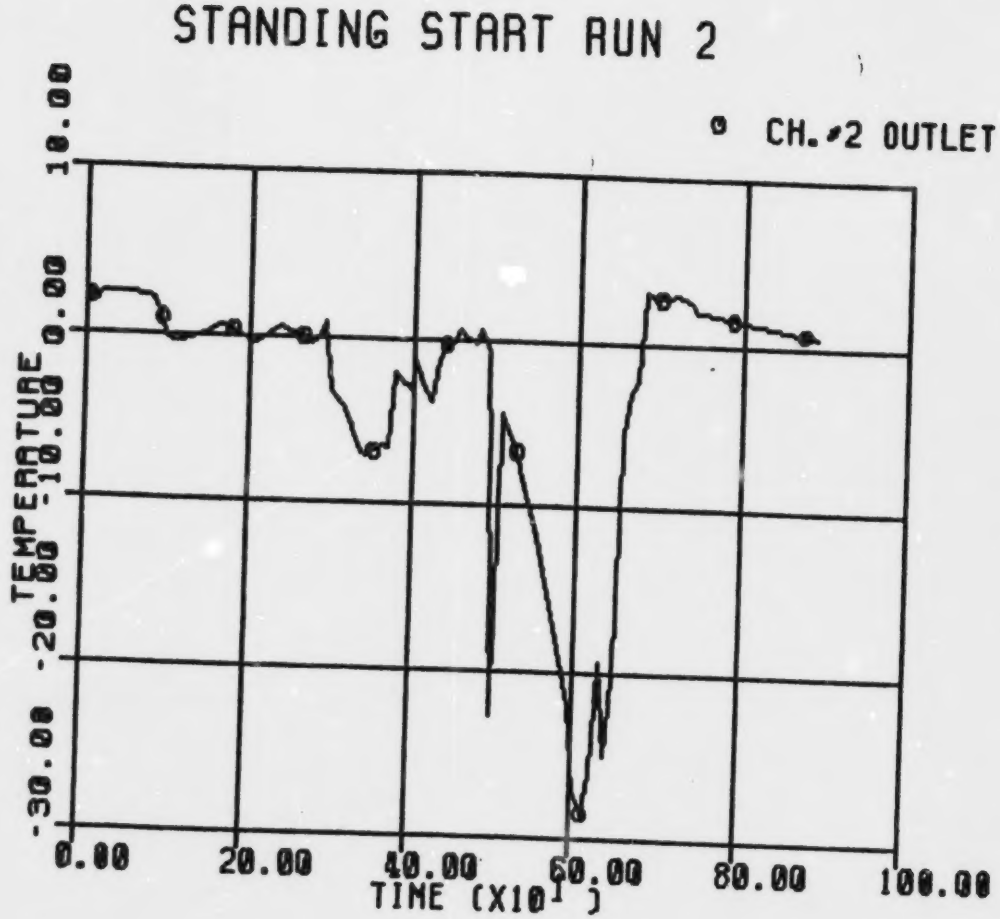

STANDING START RUN 2
CH.#2 OUTLET MINUS CH.#2 INLET
TEMPERATURE
10.00
0.00
-10.00
-20.00
-30.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-2

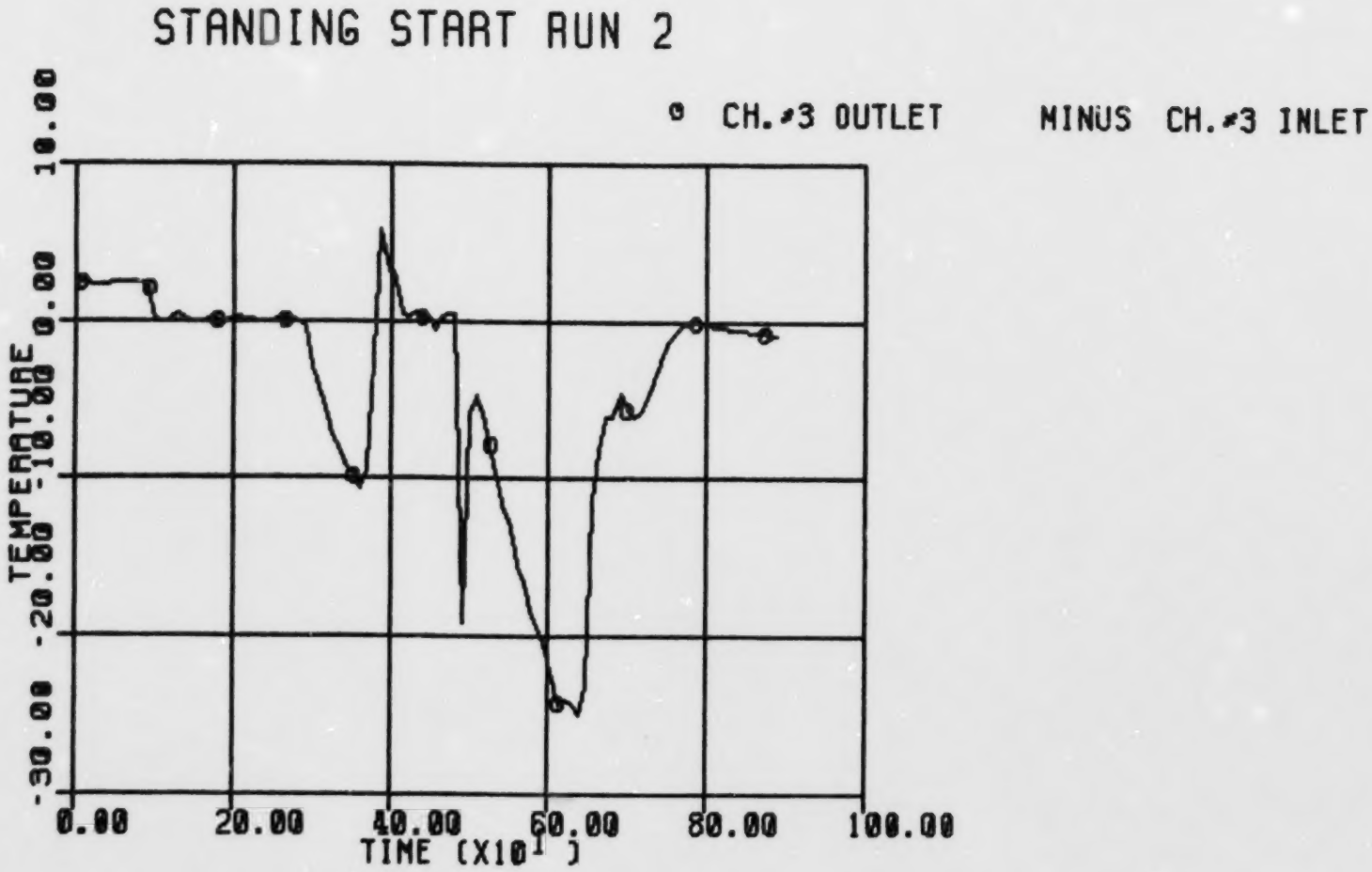

STANDING START RUN 2
CH.#3 OUTLET
MINUS CH.#3 INLET
TEMPERATURE
10.00
0.00
-10.00
-20.00
-30.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10¹)

FIGURE 3.5-3

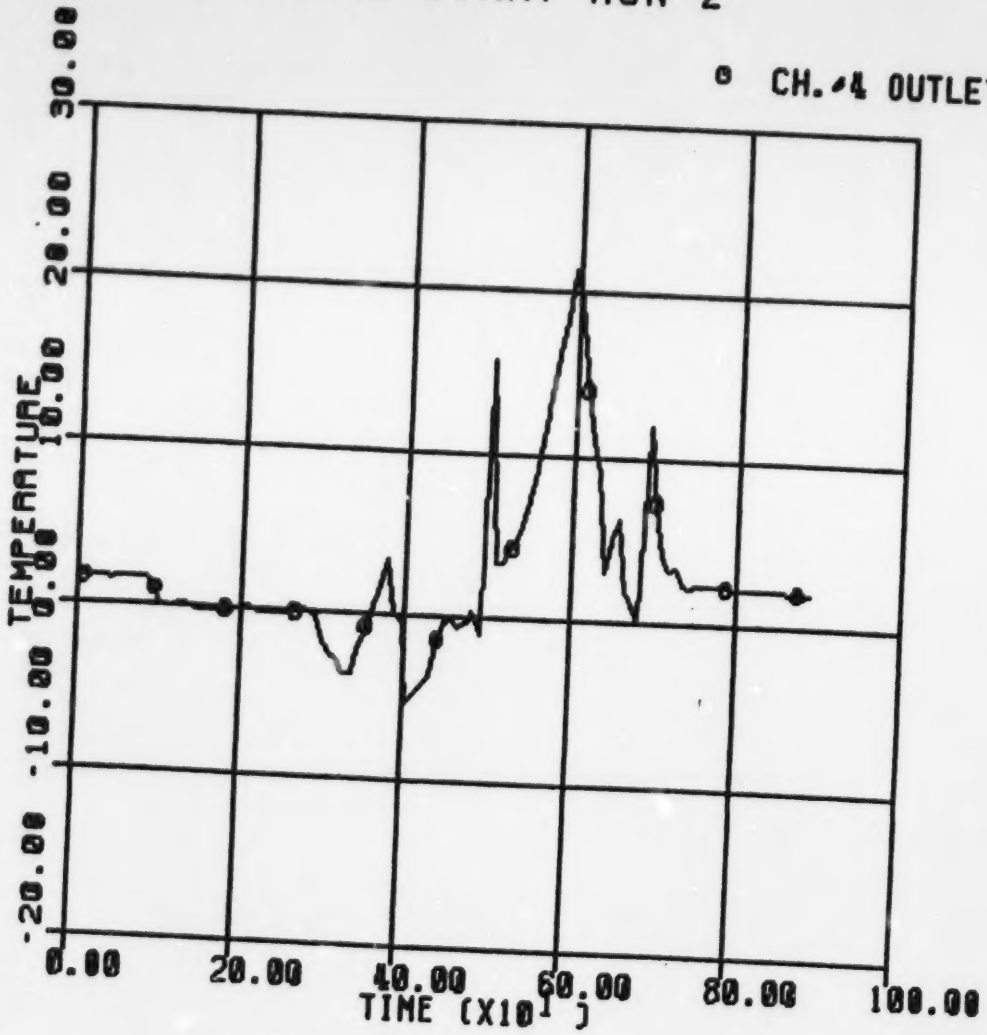

STANDING START RUN 2
CH.#4 OUTLET MINUS CH.#4 INLET
TEMPERATURE
30.00
20.00
10.00
0.00
-10.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10^1)

FIGURE 3.5-4

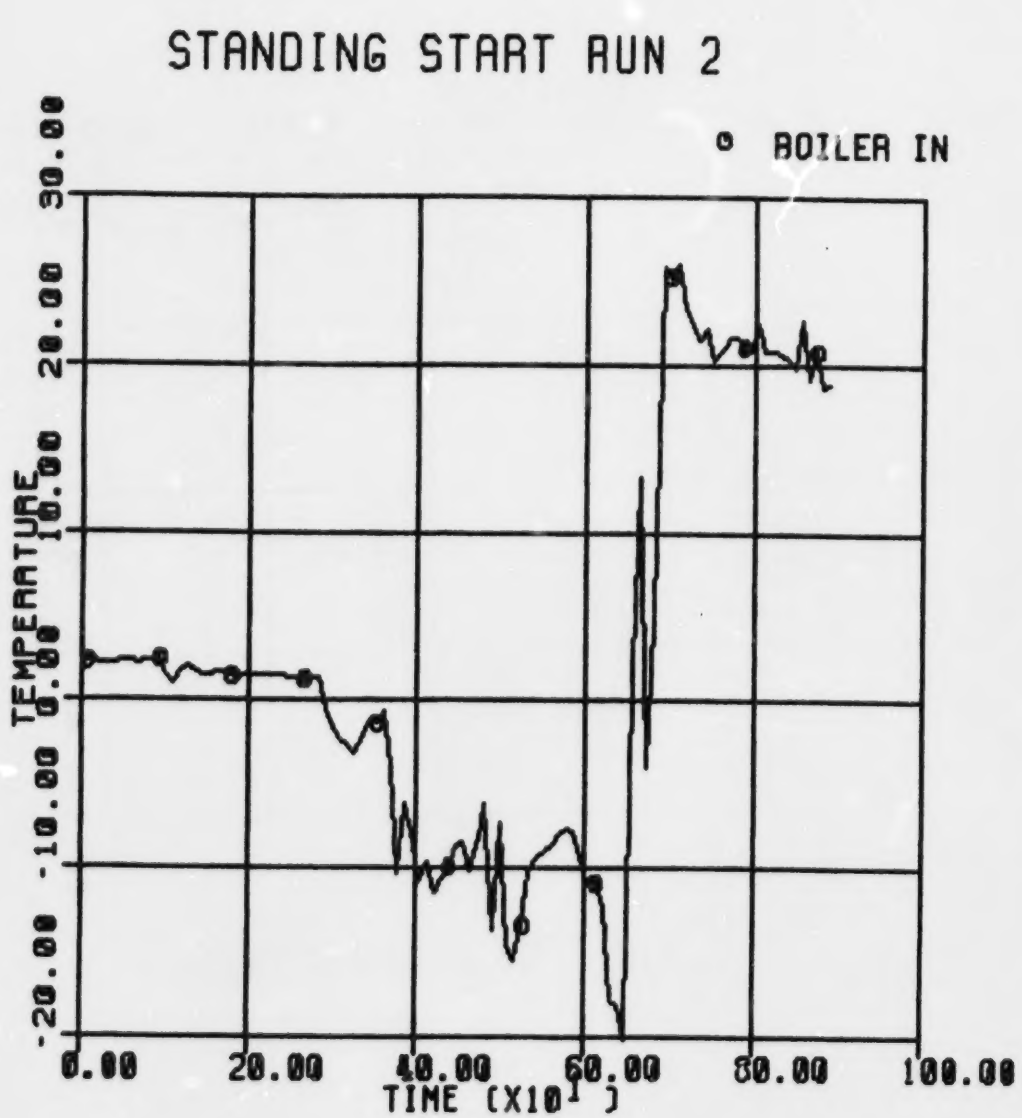

STANDING START RUN 2
BOILER IN
MINUS BOILER OUT
30.00
20.00
10.00
0.00
-10.00
-20.00
TEMPERATURE
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-5

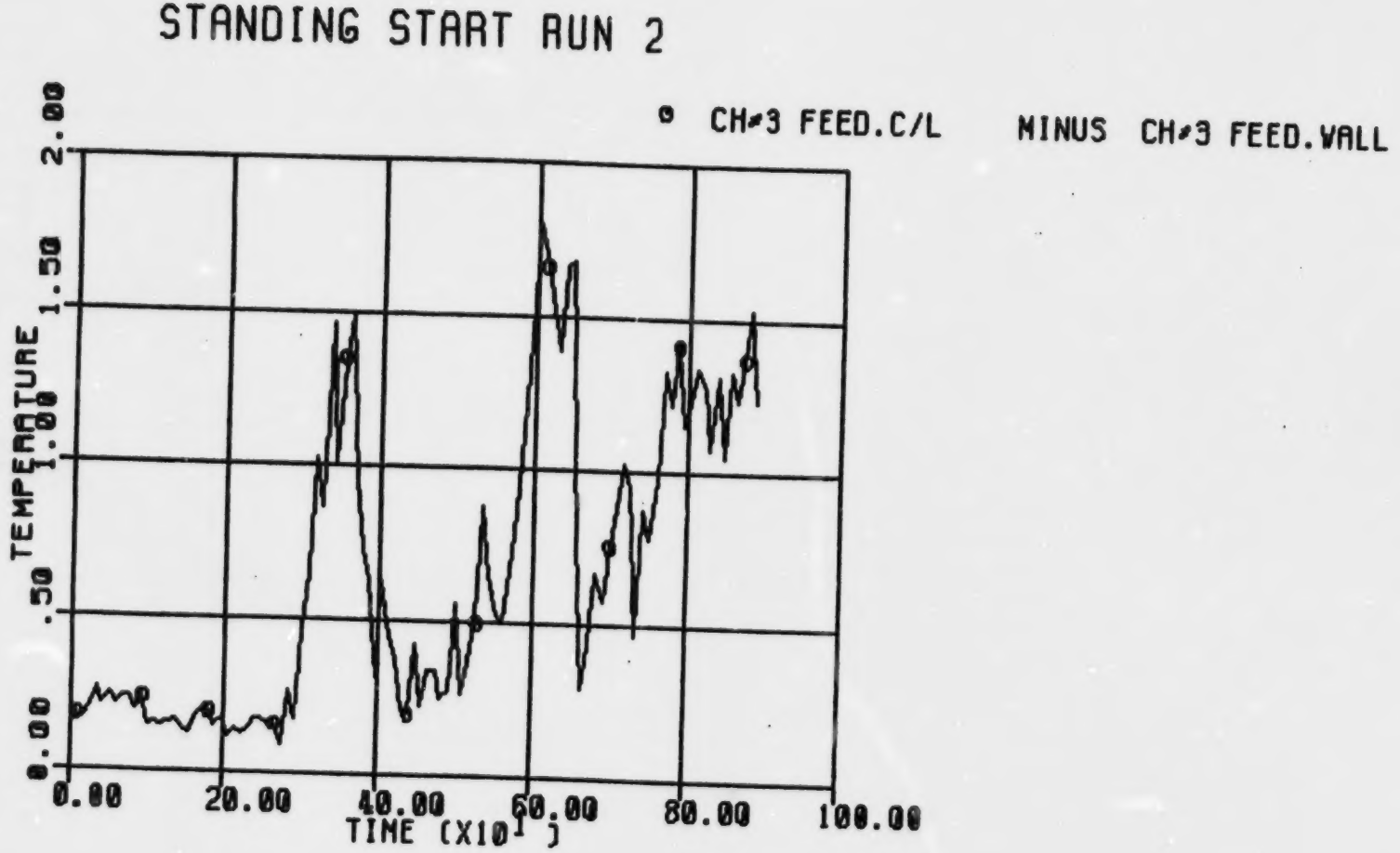

STANDING START RUN 2
CH#3 FEED.C/L
MINUS CH#3 FEED.WALL
TEMPERATURE
2.00
1.50
1.00
.50
0.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-6

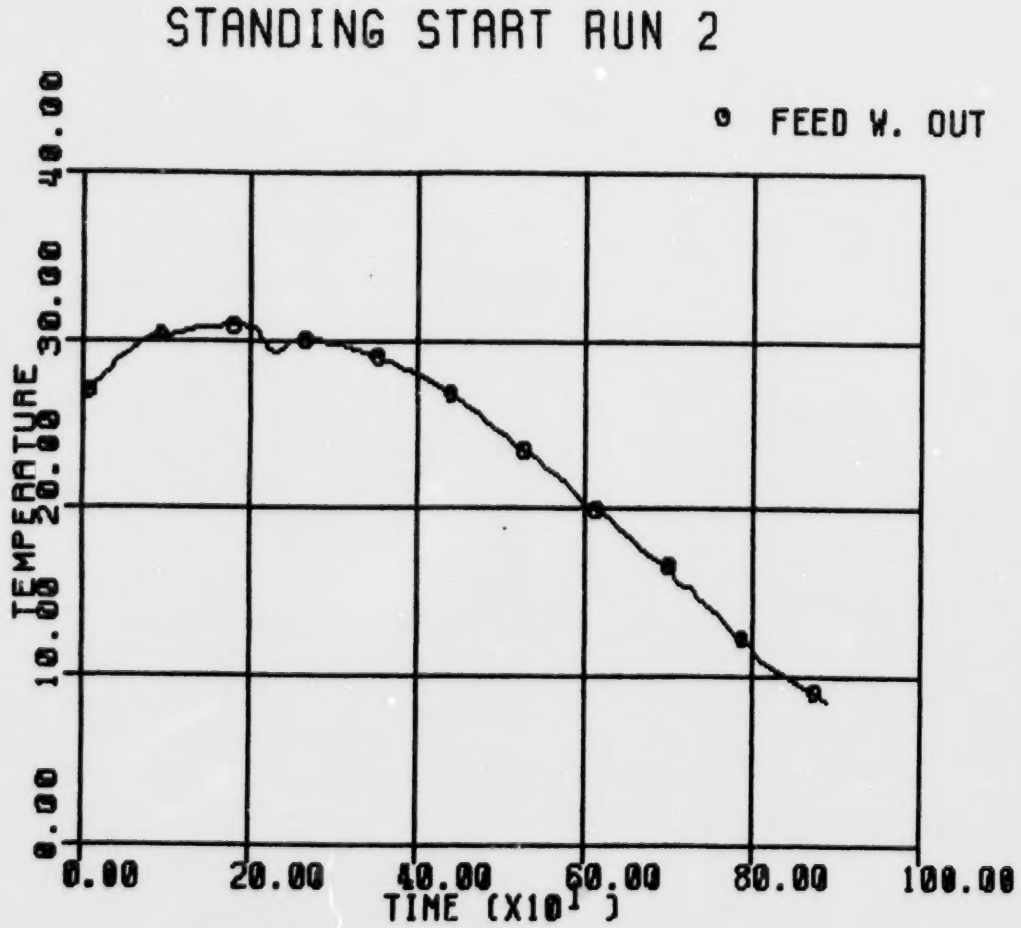

STANDING START RUN 2
° FEED W. OUT
MINUS FEED W. IN
TEMPERATURE
0.00
10.00
20.00
30.00
40.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-7

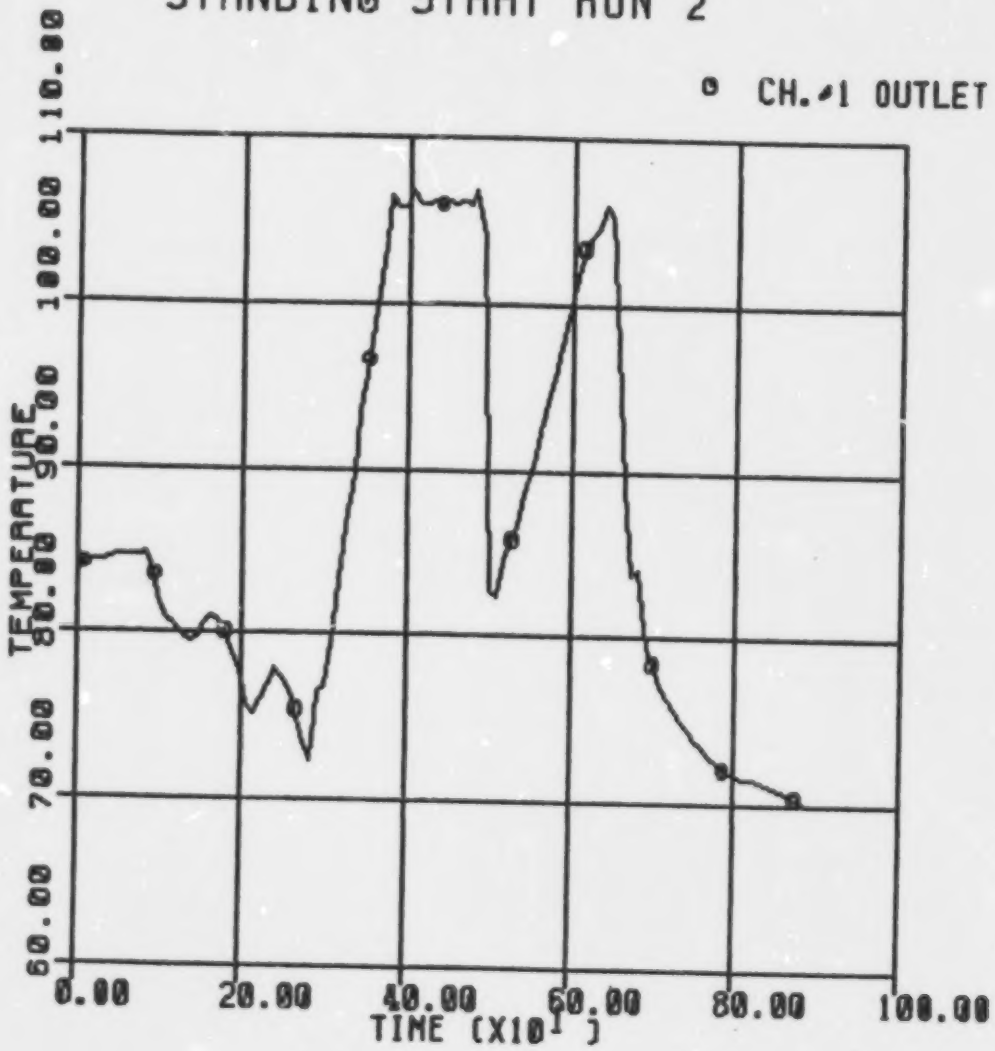

STANDING START RUN 2
CH. #1 OUTLET
TEMPERATURE
110.00
100.00
90.00
80.00
70.00
60.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-8

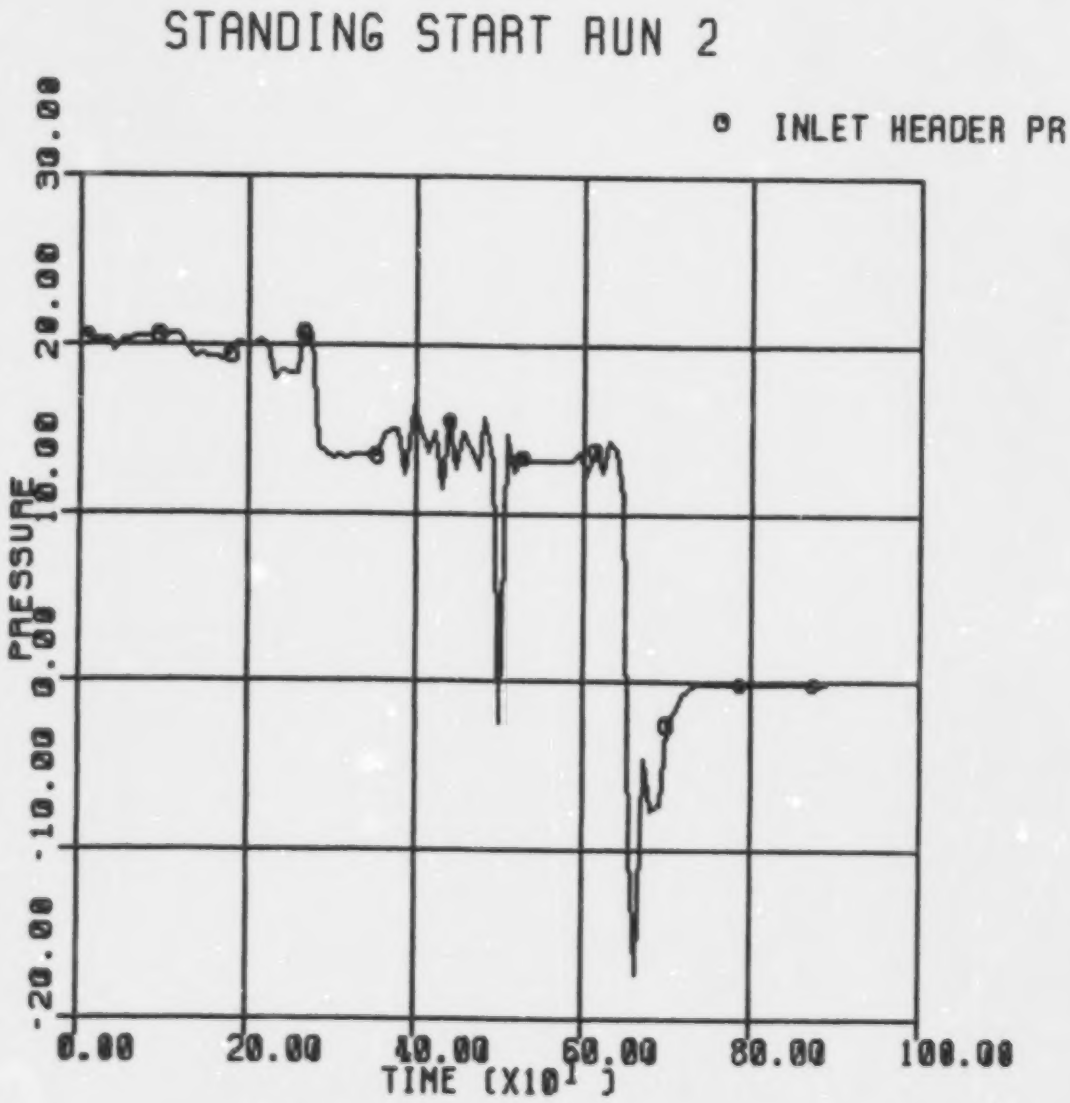

STANDING START RUN 2
INLET HEADER PR
PRESSURE
30.00
20.00
10.00
0.00
-10.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-9

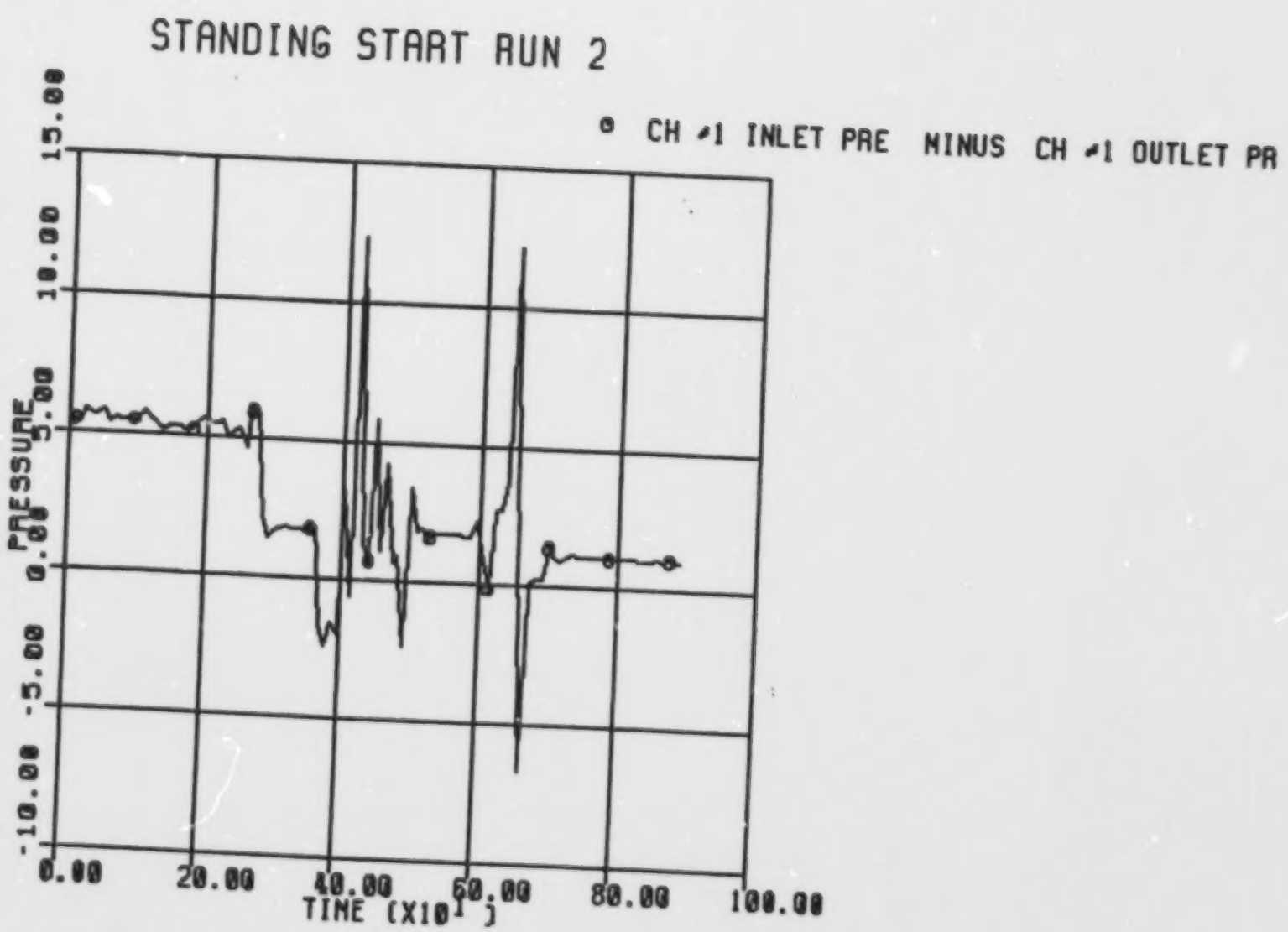

STANDING START RUN 2
CH #1 INLET PRE MINUS CH #1 OUTLET PR
PRESSURE
15.00
10.00
5.00
0.00
-5.00
-10.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10 j)

FIGURE 3.5-10

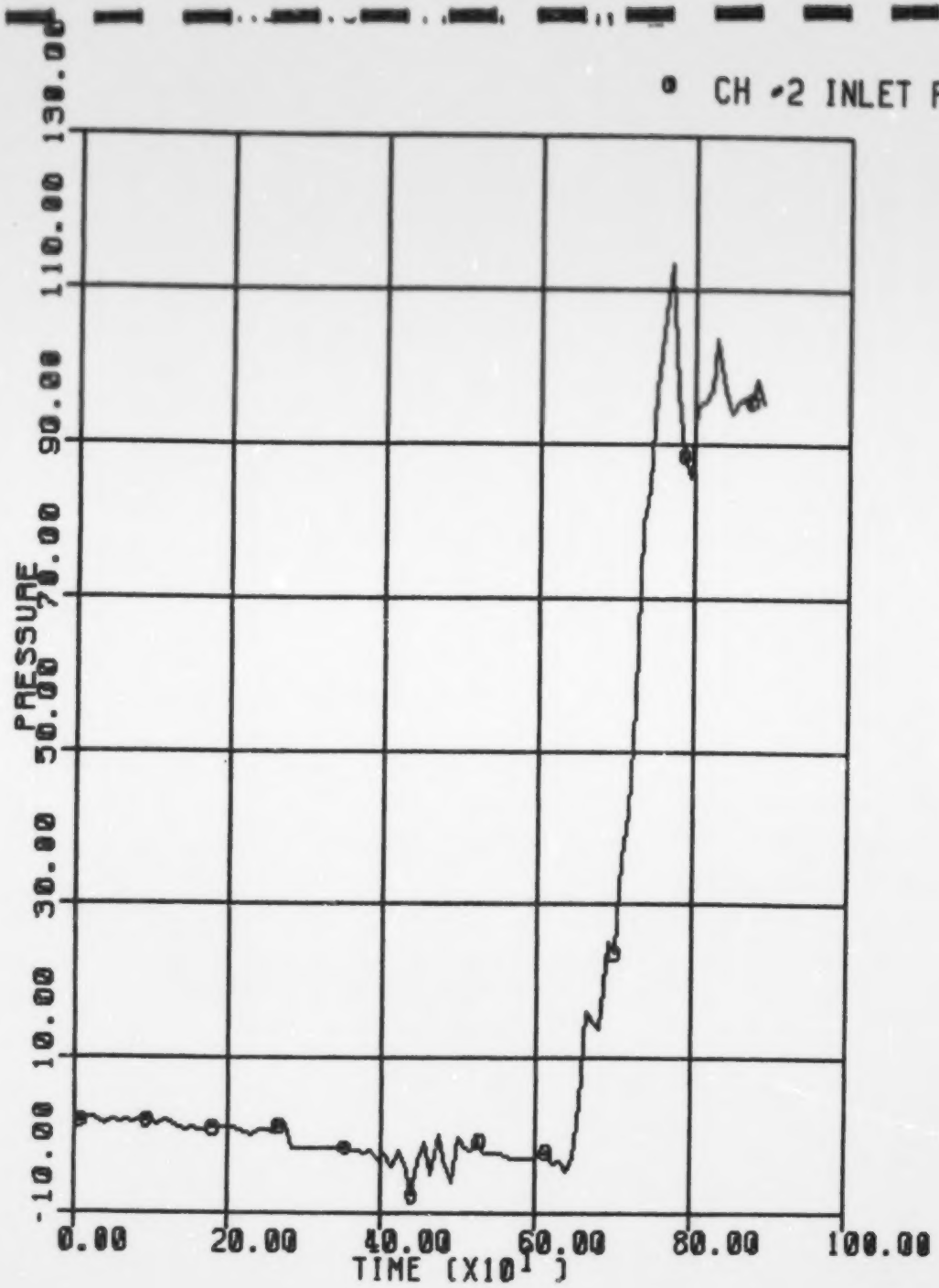

CH -2 INLET PRE MINUS CH -2 OUTLET PR
PRESSURE
-10.00
10.00
30.00
50.00
70.00
90.00
110.00
130.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10¹)

FIGURE 3.5-11

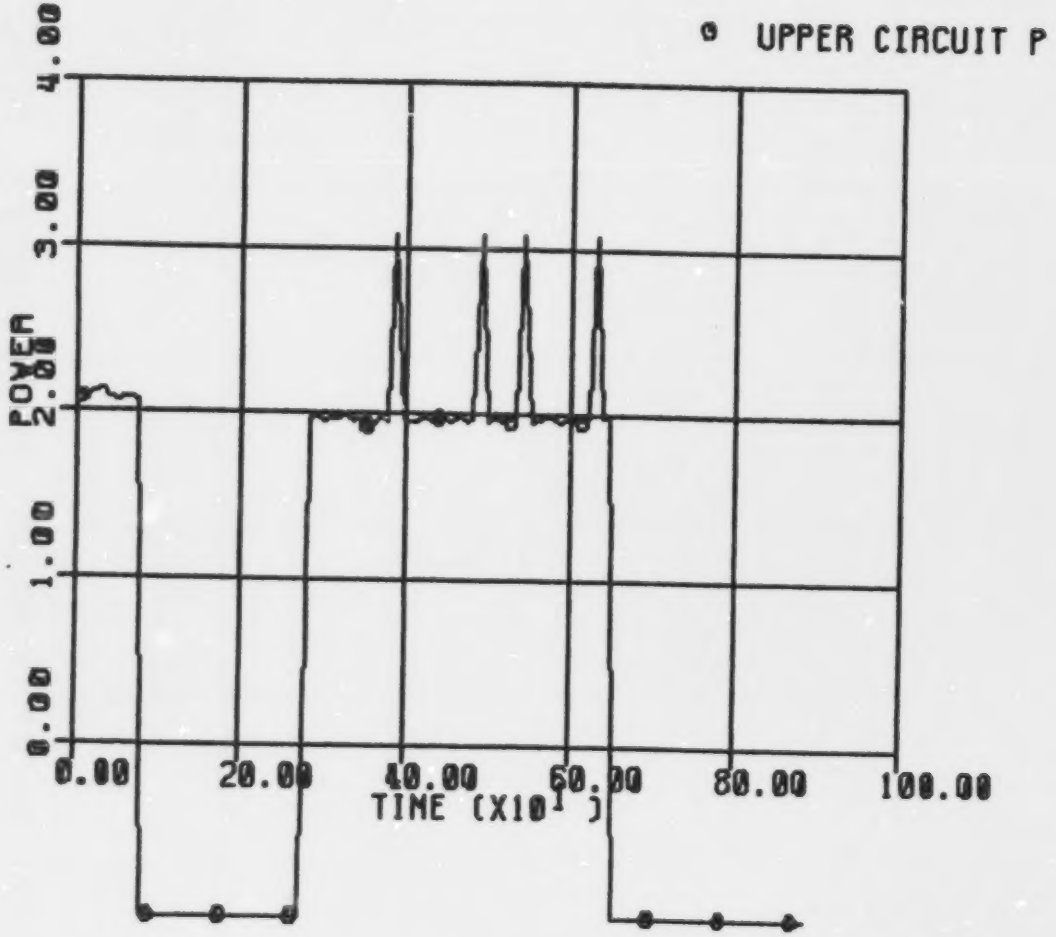

STANDING START RUN 2
UPPER CIRCUIT P
POWER
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
TIME (X10)

FIGURE 3.5-12

This experiment provided particularly violent two phase flows in the heated channels and feeders. Figure 3.5-6 shows the temperature difference between the centre-line of the channel 3 outlet feeder flow path and the inner wall of the outlet feeder. Before the pumps were shut off, centre-line temperature and wall temperatures were equal, and after the pumps were shut off, feeder centre-line temperature increased relative to that at the feeder wall. This behaviour indicates reflux cooling in the system. The hot steam/water mixture flows out of the heated channel into the boiler where it is cooled. The cool condensate flows down the feeder pipe walls and back into the heated channel. Reflux cooling was also observed in the other experiments as shown in figures 3.2-8, 3.3-6 and 3.4-6.

3.6 Pressure Instrumentation Test

This test was done to establish suitability of pressure instrumentation for measuring small pressure differences around the loop. The pumps were run at a speed which gave flow comparable to that observed in a single phase thermosyphoning test, as determined by timing particle movement using a stop watch. Figure 3.6-1 shows the differential pressure in channel 1 during the test. As shown in the figure, a pressure differential of about 0.1 kPa was observed across the heated channel, and the instrumentation was capable of measuring the differential.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The tests done so far with the flow visualization rig demonstrate the capabilities of the rig and the data acquisition system. The following characteristics were observed;

(1) Single phase thermosyphoning will remove power up to 7 kW depending upon the approach to the single phase thermosyphoning condition.

(2) In two phase conditions, the observed flow patterns showed the same characteristic. Flows in the two channels of each pass opposed each other.

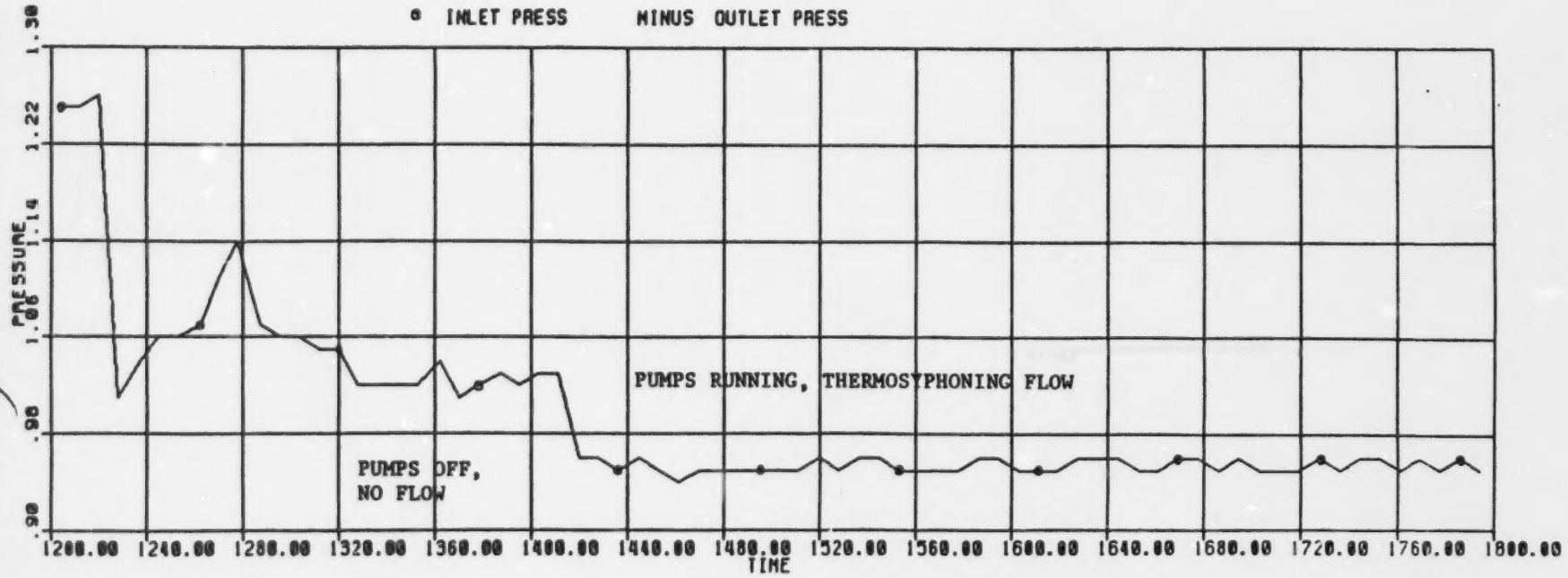
(3) Mass flux in the rig during single phase thermosyphoning compares well with the design predictions.

The modifications presently being made to the flow visualization rig include addition of two heated channels, the option of enlarging the headers, and the option of reducing inlet feeder size.

In the experiments done to date, the two phase flow pattern which developed ensured intermittent cooling of each heated channel. Forward flow in one channel in a pass forces reverse flow in the other channel. However, the two passes are not well coupled, since both (1+, 2-, 3-, 4+) and (1+, 2+, 3-, 4-) flow patterns were observed. The addition of a third channel in each pass will provide another flow path. This should simulate the reactor with many flow paths more closely. The reduced inlet feeder size will represent the design of the real reactor, and show the effects of feeder asymmetry on natural circulation flows.

Figure 3.6-1:

PUMP TEST



APPENDIX A

DESCRIPTION OF THERMOCOUPLES

Description of Thermocouples

Type "T" (copper-constantan) thermocouples were chosen for the flow visualization rig to meet sensitivity requirements for measuring small temperature differences around the loop. Outputs from the sixteen thermocouples are fed into the HP 3497 A data logger, which contains an RTD temperature measuring circuit used to determine the reference temperature. In the data logging procedure, output voltage from the RTD is measured first, then outputs from the sixteen thermocouples around the loop are measured. The measured output from each thermocouple is the difference between the copper-constantan junction potential at the thermocouple tip in the rig, and the junction where the constantan thermocouple lead joins the copper wiring within the data logger.

The outputs are transmitted via the HP 85 to the VAX 11/750 where software compensation is used to convert the measured voltages to temperature. The following procedure is used:

1) Using the temperature/voltage characteristic of the RTD circuit, the reference junction output is converted to an equivalent thermocouple voltage. The conversion is done using equation A-1.

$$V_{TE} = A_1 + A_2 V_R + A_3 V_R^3 \qquad \text{A-1}$$

where V_{TE} = equivalent thermocouple voltage
V_R = measured RTD voltage

Values for the coefficients A_1, A_2 and A_3 are given in Table A-I.

The equivalent thermocouple voltage is added to each measured thermocouple output to give the voltage across the junction at the thermocouple tip within the rig:

$$V_A = V_{TM} + V_{TE} \qquad \text{A-2}$$

Where V_A is the thermocouple tip voltage used for conversion to temperature and V_{TM} is the measured thermocouple voltage.

The temperature at each location is calculated from V_A using equation A-3.

$$T = b_1 + b_2V_A + b_3V_A^2 + b_4V_A^3 + b_5V_A^4 + b_6V_A^5 + b_7V_A^6 + b_8V_A^7 \qquad \text{A-3}$$

The coefficients are given in table A-I.

TABLE A-I

COEFFICIENTS USED IN SOFTWARE

COMPENSATED THERMOCOUPLE CALCULATIONS

Coefficient	Value
A_1	-4.050178×10^{-6}
A_2	3.894025×10^{-4}
A_3	4.022424×10^{-6}
b_1	.10086091
b_2	25727.94369
b_3	-767345.8295
b_4	78025595.81
b_5	-9247486589.
b_6	6.97688×10^{11}
b_7	-2.66192×10^{13}
b_8	3.94078×10^{14}

APPENDIX B

DESCRIPTION OF PRESSURE MEASUREMENTS

Description of Pressure Measurements

Six pressure measurements are made on the flow visualization rig using Statham Laboratory differential pressure cells. Table B-I indentifies the D/P cell locations around the flow path within the flow visualization rig. The sensitivity of each cell is shown in the table. Specifications for the differential pressure cells are included at the end of the appendix.

The D/P cell on the inlet header measures pressure relative to atmosphere. A reference pressure is used to allow the use of instruments with high sensitivity at the channel inlet and outlet locations. High sensitivity is required at the channel inlet and outlet to allow the calculation of channel differential pressure. Figure B-1. illustrates the D/P cell connections.

Instrument calibration for the channel pressure measurement cells was done using a water manometer, and a mercury manometer was used for the ±10 psid D/P cells on the inlet header and reference reservoir. Figures B-2 to B-7 show the calibration data for the pressure instruments. The D/P cell output varies linearly with pressure differential, and straight line least squares fits are used to calculate differential pressures across the cells as a function of cell output. Pressure at each instrumented location within the rig is obtained by measuring D/P cell output voltage and converting it to cell differential pressure using the fit to the calibration data. Guage pressures at the inlet header and pressure reservoir are obtained directly from the D/P cells. Pressures at the channel inlet and oulet locations are obtained by adding the differential pressure measurement to the guage pressure measured in the reference reservoir.

As for all the rig instrumentation, calculation of pressures and pressure differentials is done with software written for the VAX 11/750 computer.

TABLE B-I

PRESSURE INSTRUMENT

LOCATIONS IN THE FLOW VISUALIZATION RIG

Measurement Location	D/P Cell Range (psid)
Inlet Header	±10
Channel 1 In	± 2
Channel 1 Out	± 2
Channel 2 In	± 1
Channel 2 Out	± 2
Reference	±10

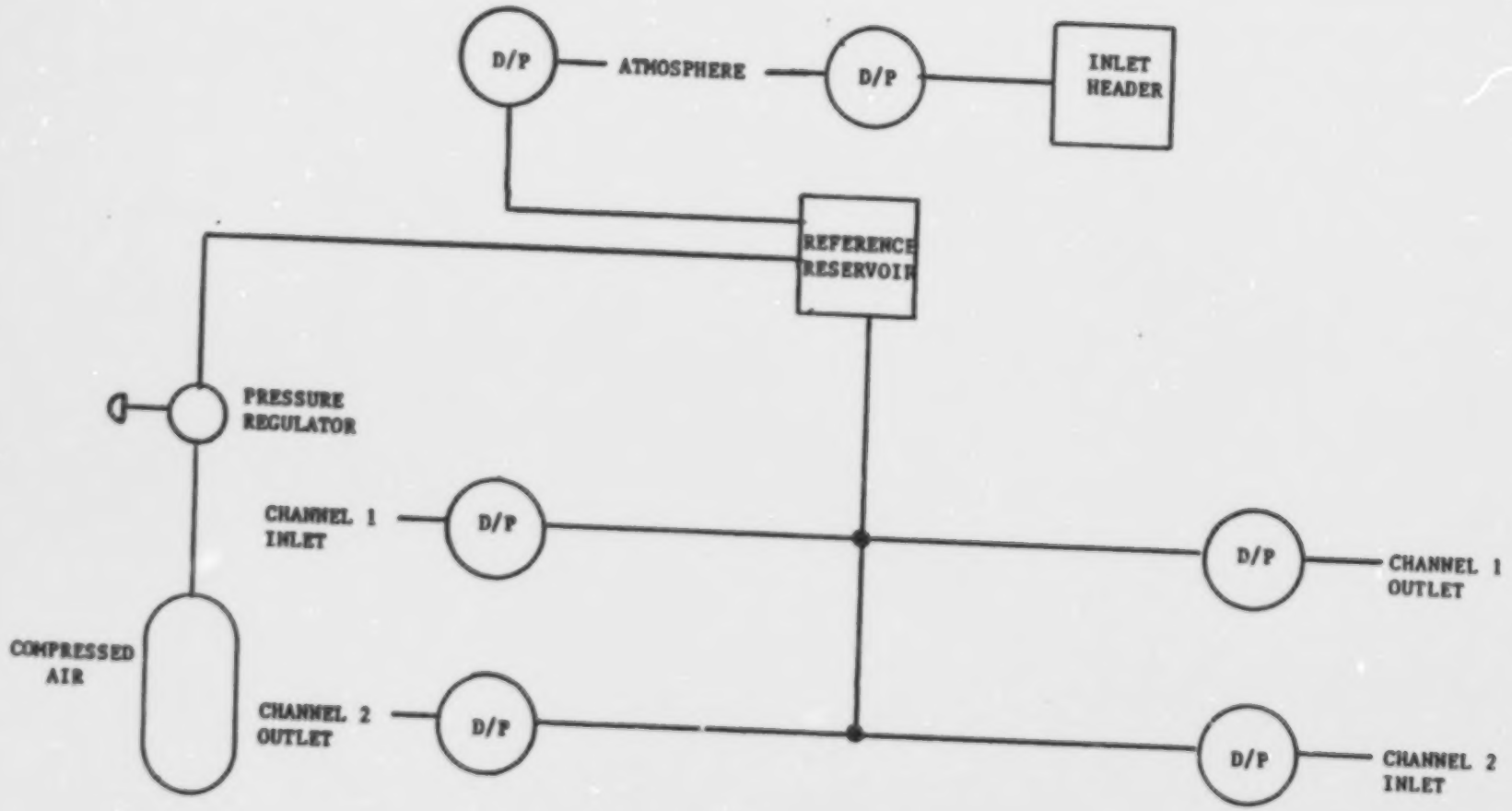
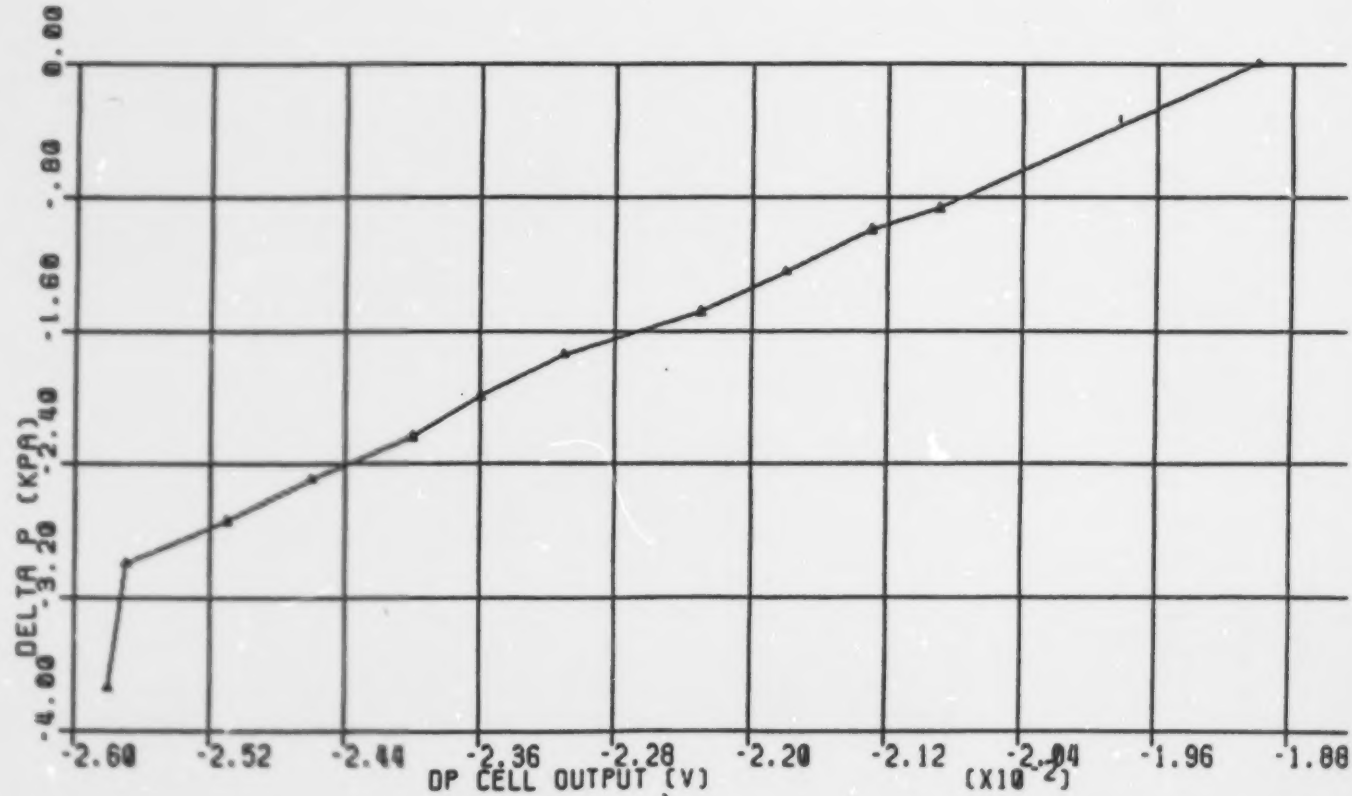


FIGURE B-1: FLOW VISUALIZATION RIG PRESSURE INSTRUMENTATION

FIGURE B-2:

FLOW VISUALIZATION RIG

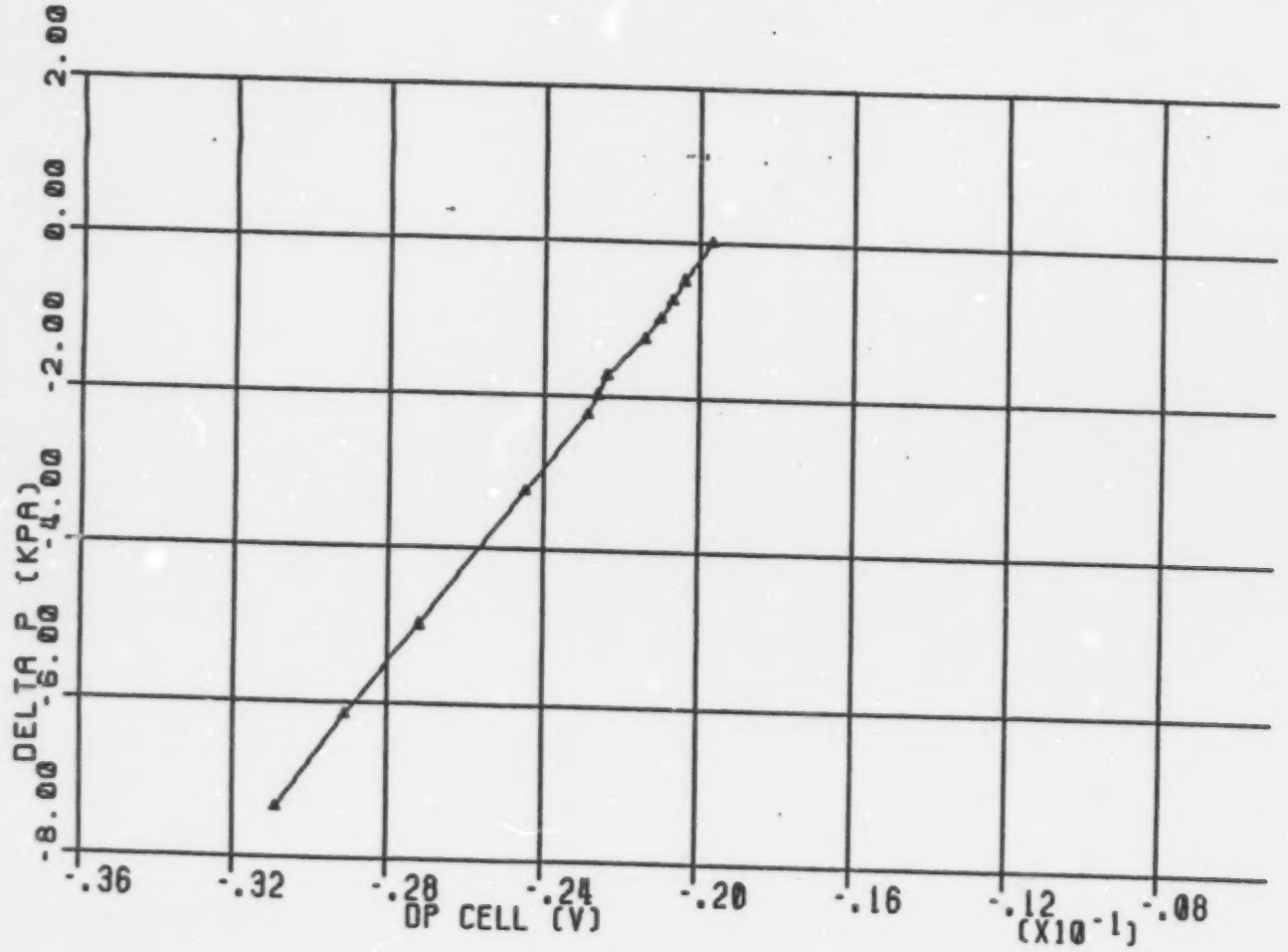
DP CELL CALIBRATION - CHANNEL 2 IN



FLOW VISUALIZATION RIG

FIGURE B-3:

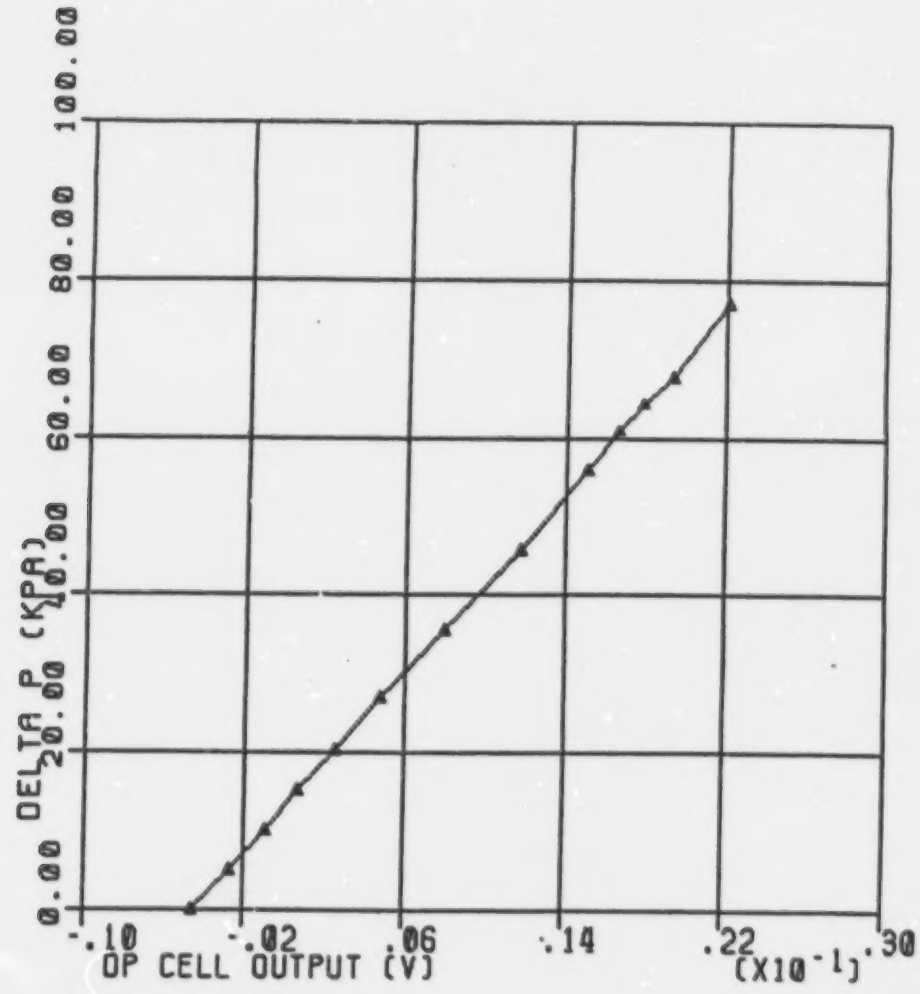
D/P CELL CALIBRATION - CHANNEL 1 OUT



FLOW VISUALIZATION RIG

FIGURE B-4:

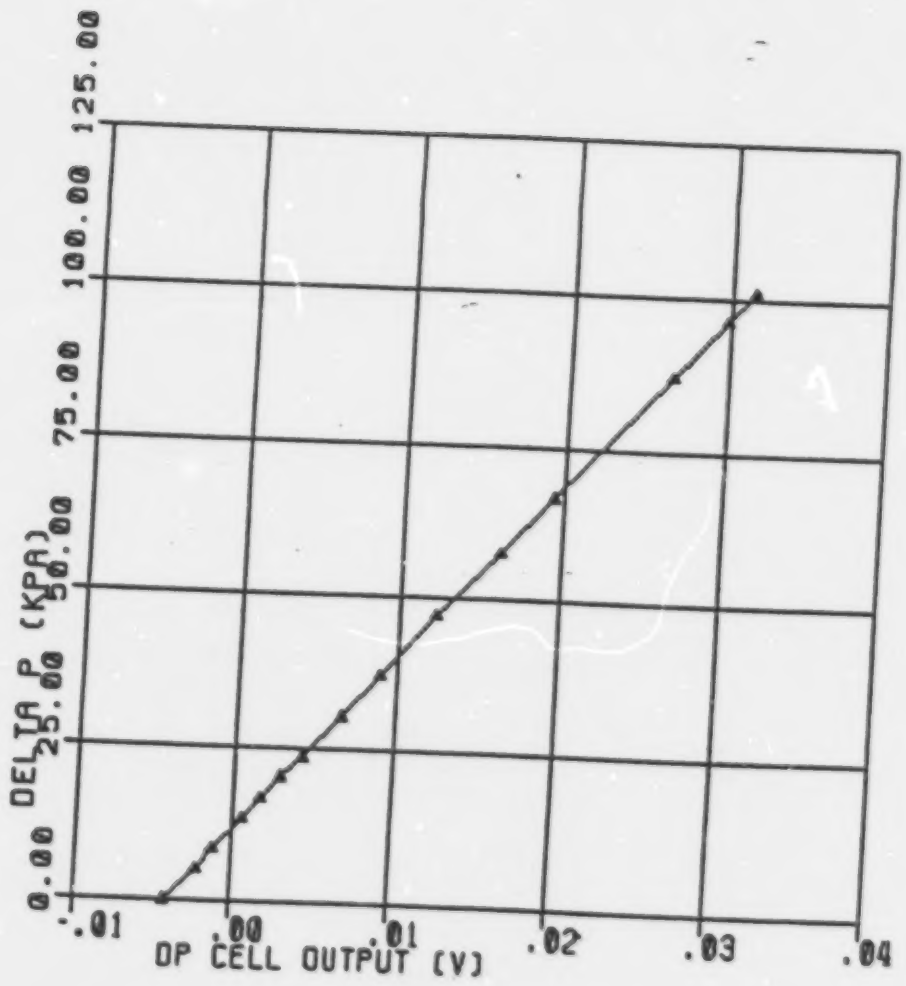
DP CELL CALIBRATION - INLET HEADER



FLOW VISUALIZATION RIG

FIGURE B-5:

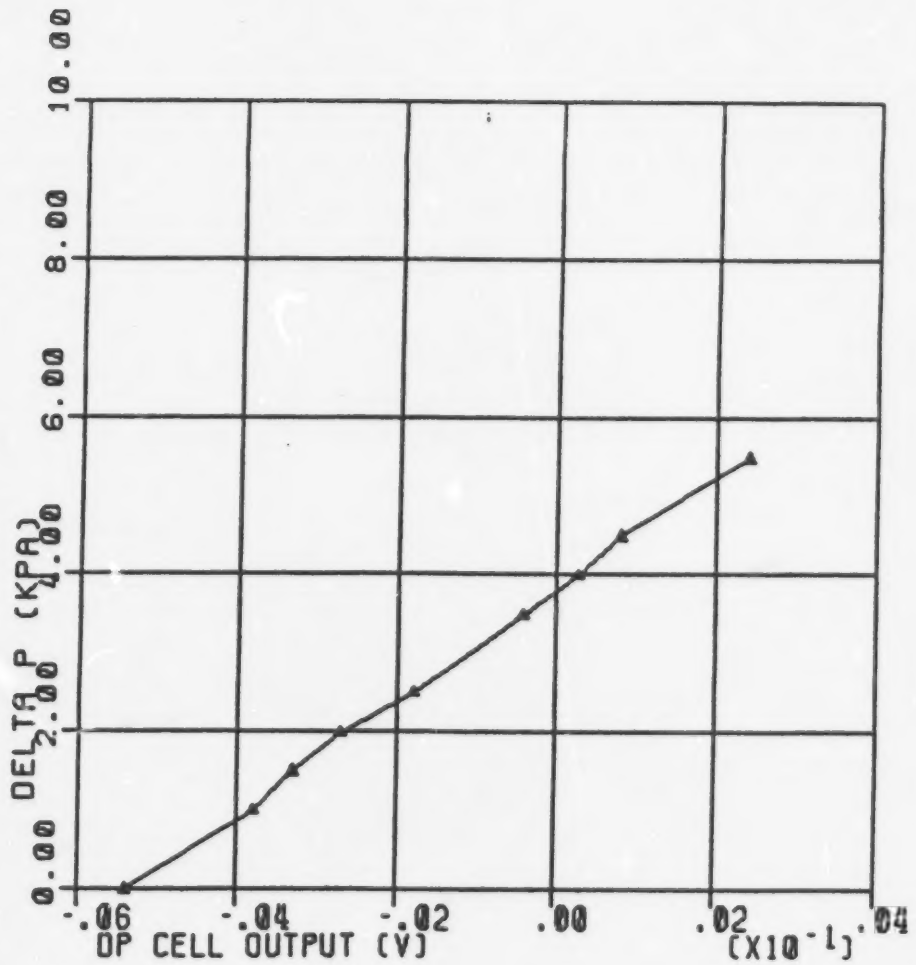
DP CELL CALIBRATION - REFERENCE CELL



FLOW VISUALIZATION RIG

FIGURE B-6:

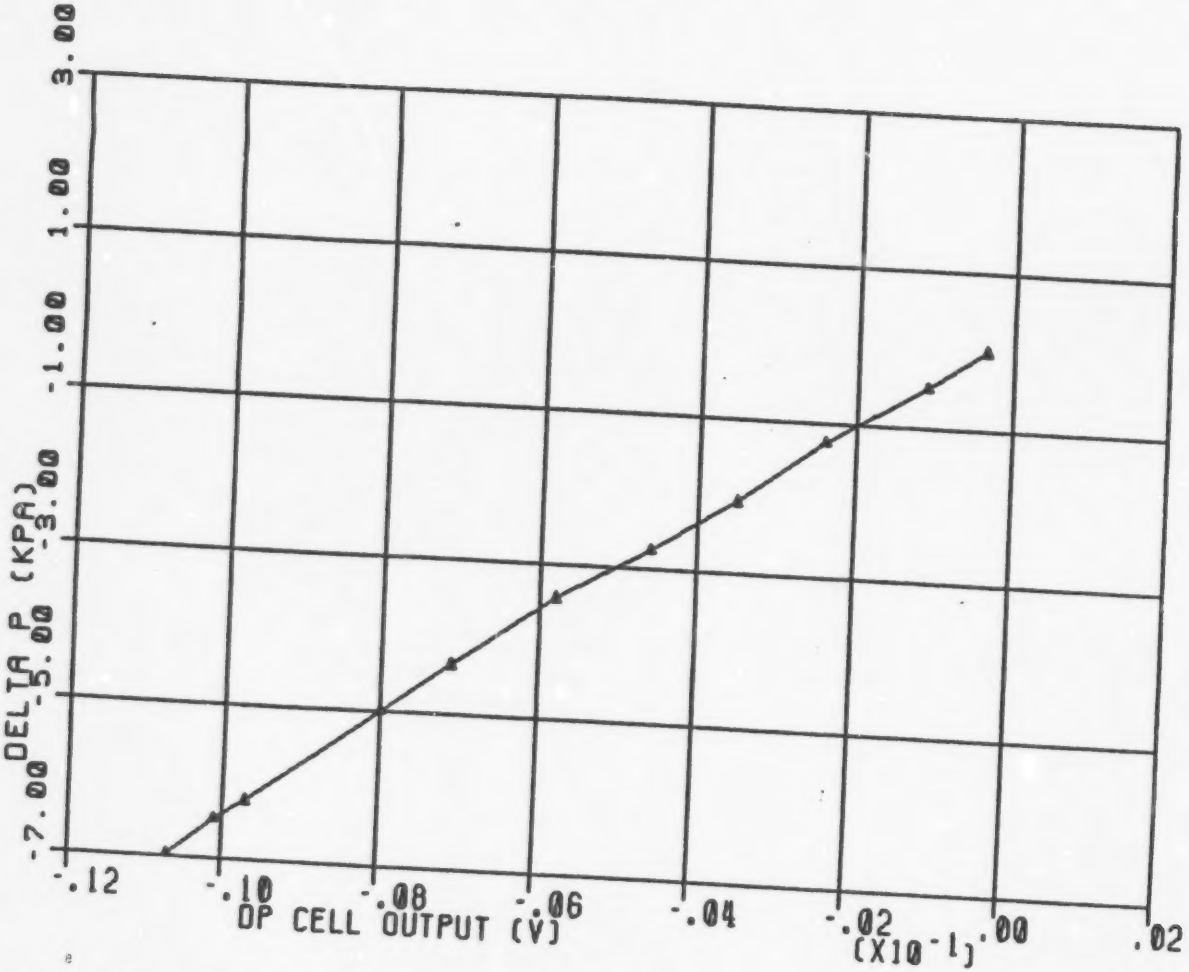
DP CELL CALIBRATION - CHANNEL 1 IN



FLOW VISUALISATION RIG

FIGURE C-7:

D/P CELL CALIBRATION - CHANNEL 2 OUT



APPENDIX C

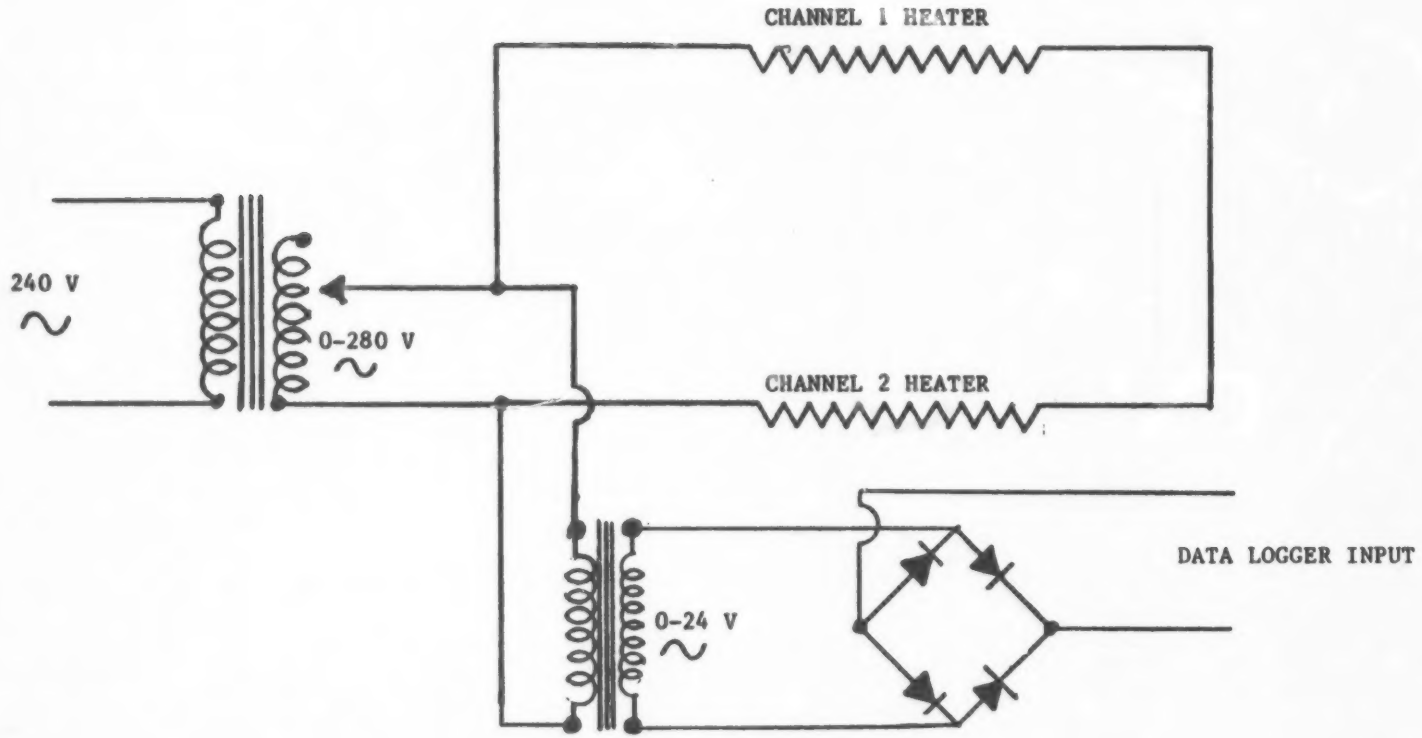
POWER MEASUREMENT

Power Measurement

Figure C-1 shows the flow visualization rig power input circuitry, and the circuit used to measure channel power. The data logger is used to measure voltage across the secondary windings of the step-down transformers, and this voltage is transmitted to the VAX 11/750 through the HP-85. A calibration curve was obtained to relate channel power to voltage measured with the data logger. Figure C-2 shows the relationship between circuit power (2 channels) and voltage measured with the data logger.

The curve is the product of measured current and voltage in the heater circuit presented as a function of voltage measured across the secondary winding of the step-down transformer.

The power in each pair of heated channels (1 & 2, 3 & 4) is given by $P = .1768 - .2004\ V + .07312\ V^2 - .0046V^3 + .0001\ V^4$
where P = power in kilowatts
V = measured voltage



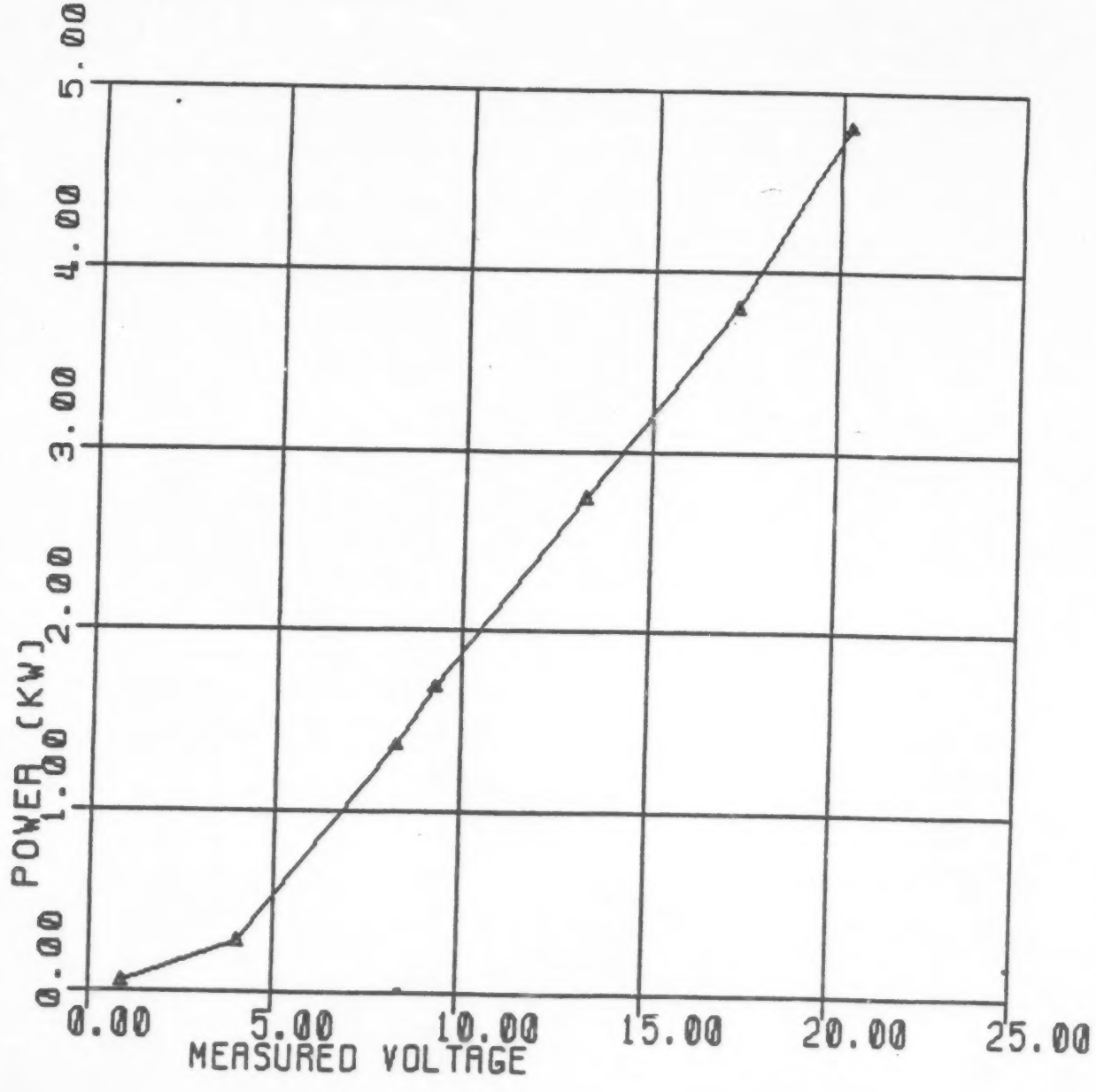
NOTE: Each pair of channel supplied by this circuit.

FIGURE C-1: FLOW VISUALIZATION RIG POWER SUPPLY CIRCUIT

FLOW VISUALIZATION RIG

FIGURE C-2:

POWER CALIBRATION



APPENDIX D

SOPHT INPUT DATA FOR
FLOW VISUALIZATION RIG
SCALING VERIFICATION SIMULATIONS

EXHIBIT D.1

FLOW VISUALIZATION RIG DATA

TABULATION OF INPUT DATA CARDS

```
CARD   TOTAL
NUMBER ERRORS
                1         2         3         4         5         6         7         8
       12345678901234567890123456789012345678901234567890123456789012345678901234567890
     1     0   *START BATCH  CARD              BF RIG001                10        10   5..0.5.
     2     0   RIG001      SOPHT MODEL OF THERMO-HYDRAULICS RIG-VR 2. COLD  APR 9,1984
     3     0   *NLIST        1
     4     0       1    1    12    0    0 .105  -02 .398  +03      .357  +03      PIPING
     5     0            2    12    0..306  -03 .101  +01 .23  -01-.500  +00 .119  -02 .00000
     6     0         .306  -03 .306  -03              .5   +00       0    0 .000
     7     0       2    1    12    0    0 .905  -03 .402  +03      .357  +03      INLET HDR      1
     8     0            3    12    0 .71   -02 .127  -00 .932  -01-.932  -01 .000  +00 .00000
     9     0          .71   -02 .71   -02              2.5  -01       0    0 .000
    10     0            4    12    0 .71   -02 .127  -00 .932  -01-.932  -01 .000  +00 .00000
    11     0          .71   -02 .71   -02              2.5  -01       0    0 .000
    12     0       3    1    12    0    0 .1    -02 .100  +04      .357  +03      INLET FDR 1
    13     0            5    12    0 .306  -03 .20   +01 .23  -01-.127  +01 .2    -02 .00000
    14     0         .306  -03 .306  -03              2.5  -01       0    0 .000                59
    15     0       5    1    12    0    0 .203  -03 .100  +04      .357  +03      END FIT 1
    16     0            6    12    0 .299  -03 .69   00 .448  -02               .1    -02 .00000
    17     0         .299  -03 .299  -03              2.5  -01       0    0 .000
    18     0       4    5    22    1    1 .469  -03 .100  +04      .362  +03      REACTOR 1
    19     0            7    22    0 .299  -03 .157  +01 .448  -02               .2    -02 .00000
    20     0         .299  -03 .299  -03              2.5  -01       0    0 .000
    21     0       7    1    12    0    0 .203  -03 .100  +04      .363  +03      END FIT 1
    22     0            8    12    0 .299  -03 .69   00 .448  -02               .1    -02 .00000
    23     0         .299  -03 .299  -03              2.5  -01       0    0 .000                60
    24     0       8    1    12    0    0 .1    -02 .100  +04      .363  +03      OUTLET FDR 1
    25     0           10    12    0 .306  -03 .20   +01 .23  -01+.127  +01 .2    -02 .00000
    26     0         .306  -03 .306  -03              2.5  -01       0    0 .000
    27     0       4    1    12    0    0 .1    -02 .100  +04      .357  +03      INLET FDR 2
    28     0           29    12    0 .306  -03 .20   +01 .23  -01-.127  +01 .2    -02 .00000
    29     0         .306  -03 .306  -03              2.5  -01       0    0 .000
    30     0      29    1    12    0    0 .203  -03 .100  +04      .357  +03      END FIT 2
    31     0           28    12    0 .299  -03 .69   00 .448  -02               .1    -02 .00000
    32     0         .299  -03 .299  -03              2.5  -01       0    0 .000
    33     0      28    5    22    1    1 .469  -03 .100  +04      .363  +03      REACTOR 2
    34     0           27    22    0 .299  -03 .157  +01 .448  -02               .2    -02 .00000
    35     0         .299  -03 .299  -03              2.5  -01       0    0 .000
    36     0      27    1    12    0    0 .203  -03 .100  +04      .363  +03      END FIT 2
    37     0           9    12    0 .299  -03 .69   00 .448  -02               .1    -02 .00000
    38     0         .299  -03 .299  -03              2.5  -01       0    0 .000
    39     0       9    1    12    0    0 .1    -02 .100  +04      .363  +03      OUTLET FDR 2
    40     0          10    12    0 .306  -03 .20   +01 .23  -01+.127  +01 .2    -02 .00000
    41     0         .306  -03 .306  -03              2.5  -01       0    0 .000
    42     0      10    1    12    0    0 .905  -03 .230  +03N     .363  +03      OUTLET HDR     4
    43     0           11    12    0 .71   -02 .127  -00 .932  -01+.932  -01 .000  +00 .00000
    44     0          .71   -02 .71   -02              2.5  -01       0    0 .000
    45     0           36    12    0 .81713-00 .102  +00 .102  +00 .613  -01 .232  -02 .00000
    46     0         .36706-03 .49087-03              .00  +00       0    0 .000
    47     0      11    1    12    0    0 .105  -02 .100  +04      .363  +03      PIPING
    48     0           12    12    0 .306  -03 .101  +01 .23  -01+.500  +00 .119  -02 .00000
    49     0         .306  -03 .306  -03              .5   +00       0    0 .000
    50     0      12    1    32    2   35 .102  -02 .100  +04      .361  +03      STEAM GEN B
```

TABULATION OF INPUT DATA CARDS

CARD NUMBER	TOTAL ERRORS	1	2	3	4	5	6	7	8
		12345678901234567890123456789012345678901234567890123456789012345678901234567890							
51	0	40 32 2 .887 -03 .113 +01 .13				-01 .113	+01 0.0	-00 .00000	
52	0	.887 -03 .887 -03 .50 +00				0	0 .000		
53	0	40 1 32 2 35 102 -02 .100 +04				.360	+03	STEAM GEN 2	
54	0	41 32 2 .887 -03 .113 +01 .13				-01 .113	+01 0.0	-00 .00000	
55	0	.887 -03 .887 -03 .50 +00				0	0 .000		
56	0	41 1 32 2 35 .102 -02 .100 +04				.359	+03	STEAM GEN 2	
57	0	42 32 2 .887 -03 .113 +01 .13				-01-.113	+01 0.0	-00 .00000	
58	0	.887 -03 .887 -03 .50 +00				0	0 .000		
59	0	42 1 32 2 35 .102 -02 .100 +04				.357	+03	STEAM GEN 2	
60	0	33 32 2 .887 -03 .113 +01 .13				-01-.113	+01 0.0	-00 .00000	
61	0	.887 -03 .887 -03 .50 +00				0	0 .000		
62	0	33 1 12 0 0 .103 -02 .100 +04				.357	+03	PIPING	
63	0	15 12 0 .306 -03 .101 +01 .23				-01-.300	+00 .119	-02 .00000	
64	0	.306 -03 .306 -03 .5 +00				0	0 .000		32
65	0	15 1 12 0 0 .905 -03 .100 +04				.357	+03	INLET HDR	3
66	0	16 12 0 .71 -02 .127 -00 .932				-01-.932	-01 .000	+00 .00000	
67	0	.71 -02 .71 -02 2.5 -01				0	0 .000		
68	0	17 12 0 .71 -02 .127 -00 .932				-01-.932	-01 .000	+00 .00000	
69	0	.71 -02 .71 -02 2.5 -01				0	0 .000		
70	0	16 1 12 0 0 .1 -02 .100 +04				.357	+03	INLET FDR 3	
71	0	18 12 0 .306 -03 .20 +01 .23				-01-.127	+01 .2	-02 .00000	
72	0	.306 -03 .306 -03 2.5 -01				0	0 .000		
73	0	18 1 12 0 0 .205 -03 .100 +04				.357	+03	END FIT 3	
74	0	19 12 0 .299 -03 .69 00 .668				-02	.1	-02 .00000	
75	0	.299 -03 .299 -03 2.5 -01				0	0 .000		
76	0	19 3 22 1 1 .469 -03 .100 +04				.363	+03	REACTOR 3	
77	0	20 22 0 .299 -03 .137 +01 .668				-02	.2	-02 .00000	
78	0	.299 -03 .299 -03 2.5 -01				0	0 .000		
79	0	20 1 12 0 0 .205 -03 .100 +04				.363	+03	END FIT 3	
80	0	21 12 0 .299 -03 .69 00 .668				-02	.1	-02 .00000	
81	0	.299 -03 .299 -03 2.5 -01				0	0 .000		
82	0	21 1 12 0 0 .1 -02 .100 +04				.363	+03	OUTLET FDR 3	
83	0	23 12 0 .306 -03 .20 +01 .23				-01+.127	+01 .2	-02 .00000	
84	0	.306 -03 .306 -03 2.5 -01				0	0 .000		
85	0	17 1 12 0 0 .1 -02 .100 +04				.357	+03	INLET FDR 4	
86	0	30 12 0 .306 -03 .20 +01 .23				-01-.127	+01 .2	-02 .00000	
87	0	.306 -03 .306 -03 2.5 -01				0	0 .000		
88	0	30 1 12 0 0 .205 -03 .100 +04				.357	+03	END FIT 4	
89	0	31 12 0 .299 -03 .69 00 .668				-02	.1	-02 .00000	
90	0	.299 -03 .299 -03 2.5 -01				0	0 .000		
91	0	31 3 22 1 1 469 -03 .100 +04				.363	+03	REACTOR 4	
92	0	32 22 0 .299 -03 .137 +01 .668				-02	.2	-02 .00000	
93	0	.299 -03 .299 -03 2.5 -01				0	0 .000		
94	0	32 1 12 0 0 .205 -03 .100 +04				.363	+03	END FIT 4	
95	0	22 12 0 .299 -03 .69 00 .668				-02	.1	-02 .00000	
96	0	.299 -03 .299 -03 2.5 -01				0	0 .000		
97	0	22 1 12 0 0 1 -02 .100 +04				.363	+03	OUTLET FDR 4	
98	0	23 12 0 .306 -03 .20 +01 .23				-01+.127	+01 .2	-02 .00000	
99	0	.306 -03 .306 -03 2.5 -01				0	0 .000		
100	0	23 1 12 0 0 905 -03 .100 +04				.363	+03	OUTLET HDR	

TABULATION OF INPUT DATA CARDS

```
CARD NUMBER  TOTAL ERRORS
                  1         2         3         4         5         6         7         8
         12345678901234567890123456789012345678901234567890123456789012345678901234567890
     101         0
                   24   12   0 .71   -02 .127  -00 .952  -01+.952  -01 .000  +00 .00000
     102         0          .71  -02 .71   -02            2.5  -01       0    0 .000
     103         0     24    1   12   0    0 .105  -02 .100  +04    .363  +03     PIPING
     104         0                23   12   0 .506  -03 .101  +01 .25  -01+.500  +00 .119  -02 .00000
     105         0                .506 -03 .506  -03            .5   +00       0    0 .000
     106         0           23    1   32   2   35 .102  -02 .100  +04    .362  +03     STEAM GEN A
     107         0                43   32   2 .887  -03 .115  +01 .13   -01 .115  +01 0.0   -00 .00000
     108         0                .887 -03 .887  -03            .50  +00       0    0 .000
     109         0           43    1   32   2   35 .102  -02 .100  +04    .361  +03     STEAM GEN A
     110         0                44   32   2 .887  -03 .115  +01 .13   -01 .115  +01 0.0   -00 .00000
     111         0                .887 -03 .887  -03            .50  +00       0    0 .000
     112         0           44    1   32   2   35 .102  -02 .100  +04    .359  +03     STEAM GEN A
     113         0                45   32   2 .887  -03 .115  +01 .13  -01-.115  +01 0.0   -00 .00000
     114         0                .887 -03 .887  -03            .50  +00       0    0 .000
     ..          0           45    1   32   2   35 .102  -02 .100  +04    .357  +03     STEAM GEN A
                 0                 1   32   2 .887  -03 .115  +01 .13  -01-.115  +01 0.0   -00 .00000
                 0                .887 -03 .887  -03            .50  +00       0    0 .000
                 0           35    1 2042   2    0 .31919+03 .100  +03H    .22  +03H     SHELL SIDE
     ..u         0           36    1 2012   2    0 .31919+03 .300  +03     .163  +03     SURGE TANK
     119         1
     120         2 *AUXVC/N
     121         2       1    1 5.0    +0 901.0201  6.3403 -3 3.0    +0 6.1214 -3 2.7    -3 3.335  -1
     122         2              1.053  +4 1.4    -2 3.496  -1 6.37   +3              9.9993 +0 1.25   -2
     123         2              1.0    +0
     124         2       2    2 5.0    +0 801.0201  901.0201  1.0    +0 7.0    +00 .8    -02 .64   -02
     125         2                .1946 -03 .75370+00 .1204 +04          1000.     1000.     +0 .717351+0
     126         2              4.0    -3 1000.
     127         2
     128         2 *AFLUX/AUTO
     129         2 *ZPOWR     20.0        +0    1
     130         2              1.0          .50000    .50000
     131         2
     132         2 *NKINE
     133         2              2.981   -4 1.1742 -3 1.04368-3 2.37378-3 7.8647 -4 1.9816 -4  6.1846-4
     134         2              3.139989-2 1.21648-1 3.17329-1 1.38921+0 3.78778+0 8.9302 -4 2.82503-2
     135         3              2.88871 -22.39718 -21.03679 -11.41633 -44.75453 -3 5.     -3  1.4
                 2 *RPARM     30 0010111 1.          1.    -5    1.   -5    5.   -5    2.   -5  1.001 +0
                 3 *END   0.0
```

EXHIBIT D.2

600 MWE (G2) REACTOR

DATA

TABULATION OF INPUT DATA CARDS

```
CARD   TOTAL
NUMBER ERRORS      1         2         3         4         5         6         7         8
                   12345678901234567890123456789012345678901234567890123456789012345678901234567890

   1      0        *START BATCH  CARD              F                              10      10          0 1
   2      0             G2 SIMPLIFIED CIRCUIT. THERMOSYPHONING. PRESSURIZED. HOT
   3      0        *RLIST         2
   4      0            1    1   111          1 109      9 9739  +3       984.5           PUMP DISCHRG
   5      0                 2    11     0 394      2 817      .354       -2.65      1.19     -3
   6      0              0.394     0.394                  3 8     +2                                    36
   7      0            2    1    11           7.381      9.9995  +3       984.5           RIH-IFR-EIP   1
   8      0                 3    11     0.6392     11.86      .06545     -5.10      2.899    -2
   9      0               .3936     1.3954                 3 8     +3                                    63
  10      0            3    8    21    1    1  4.408     1 0028  +4      1100.0           REACTOR
  11      0                 4    21     0.6997     6.30       0.00798    0.0        1.741    -2
  12      0              1.595     1.595                  3.800   +3     3
  13      0            4    1    11           1.872      1 0027  +4      1162.6           END FITTING
  14      0                 5    11     0.936      2.0        0.0792     0.0        5.705    -3
  15      0              1 595     0 517                  3.8     +3     4
  16      0            5    5    11           9.49       1.0026  +4      1162.6           OULET FDR
  17      0                 6    11     0.88       10.78      0.0768     5.10       7.20     -3
  18      0              0.517     0 517                  3.8     +3
  19      0            6    1    11           1.670      9991.0          1162.4           OUTLET HDR    5
  20      0                91    11     1.036      0.806      1.1485     0.0        0.0      -3
  21      0              0.2587    0.2494                 1.9     +3
  22      0                77    11     1.036      0.806      1.1485     0.0        0.0      -3
  23      0              0.2587    0.2494                 1.9     +3
  24      0           91    1    11           .46390     9991.0          1162.40
  25      0                7    11     .257692    1.801      .405034    .3331464   1.29     -3
  26      0              0.2494    0.3082                 1.9     +3
  27      0                95    11     .088       14.8       .2364      -5.5       4.       -3
  28      0             .088      .088                   0.0
  29      0            7    1    11           .99536     9966.0          1162.6           PIPING
  30      0                8    11     .327164    3.051      .4563765   1.42685    .537619  -3
  31      0              0.3082    .536                   1.9     +3
  32      0           77    1    11           1.46       9966.0          1162.6           PIPING
  33      0                8    11     0.3008     4.85       0.438      1.76       2.264    -3
  34      0              0.2494    .536                   1.9     +3
  35      0            8    1    11           2.85       9886.0          1162.6           SG INLET HD
  36      0                9    11     2.738      1.04       1.32       1.00       6.23     -3
  37      0              1.072     1.031                  3.8     +3
  38      0            9    1    31    2    351.698      9854.0          1128.0           SG U-TUBES    9
  39      0                10    31    21.031     1.639      0.0136     1.639      0.0
  40      0              1.031     1.031                  3.8     +3
  41      0           10    1    31    2    351.698      9854.0          1100.0           SG U-TUBES    9
  42      0                11    31    21.031     1.639      0.0136     1.639      0.0
  43      0              1.031     1.031                  3.8     +3
  44      0           11    1    31    2    35 2.042     9635.0          1077.0           SG HT         9
  45      0                12    31    21.031     1.982      0.0136     1.840      2.03     -4
  46      0              1.031     1.031                  3.8     +3
  47      0           12    1    31    2    35 2.042     9635.0          1057.0           SG HT         9
  48      0                13    31    21.031     1.982      0.0136     1.840      2.03     -4
  49      0              1.031     1.031                  3.8     +3
  50      0           13    1    31    2    35 2.042     9635.0          1041.0           SG HT         9
```

TABULATION OF INPUT DATA CARDS

CARD NUMBER	TOTAL ERRORS	1	2	3	4	5	6	7	8
		12345678901	12345678901	12345678901	12345678901	12345678901	12345678901	12345678901	12345678901
31	0	14	31 21 031	1 982	0.0136	1.840	2 03	-4	
32	0	1 031	1 031		3 8	+3			
33	0	14 1	31 2 35	2.042	9635.0	1028.0		SG HT	9
34	0	15	31 21.031	1.982	0.0136	-1.840	2.03	-4	
35	0	1.031	1 031		3.8	+3			
36	0	15 1	31 2 35	2 042	9635.0	1017.0		SG HT	9
37	0	16	31 21.031	1.982	0.0136	-1.840	2.03	-4	
38	0	1.031	1.031		3.8	+3			
39	0	16 1	31 2 35	2.042	9635.0	1009.0		SG HT	9
40	0	17	31 21.031	1.982	0.0136	-1.840	2.03	-4	
41	0	1.031	1 031		3.8	+3			
42	0	17 1	31 2 35	.363	9525.0	1003.0		PREHEATER HT	15
43	0	18	31 21.031	.3462	0.0136	-.3462	0.0		
44	0	1.031	1.031		3.8	+3			
45	0	18 1	31 2 35	.363	9525.0	998.0		PREHEATER HT	15
46	0	19	31 21.031	.3462	0.0136	-.3462	0.0		
47	0	1.031	1.031		3.8	+3			
48	0	19 1	31 2 35	.363	9525.0	994.0		PREHEATER HT	15
49	0	20	31 21.031	.3462	0.0136	-.3462	0.0		
50	0	1.031	1.031		3.8	+3			
51	0	20 1	31 2 35	.363	9525.0	990.0		PREHEATER HT	15
52	0	21	31 21.031	.3462	0.0136	-.3462	0.0		
53	0	1.031	1.031		3.8	+3			
54	0	21 1	31 2 35	.363	9525.0	987.0		PREHEATER HT	15
55	0	22	31 21.031	.3462	0.0136	-.3462	0.0		
56	0	1.031	1.031		3.8	+3			
57	0	22 1	31 2 35	.363	9525.0	984.0		PREHEATER HT	15
58	0	23	31 21.031	.3462	0.0136	-.3462	0.0		
59	0	1.031	1.031		3.8	+3			
60	0	23 1	11	2.85	9316.0	984.32		SG OUTLET HD	
61	0	24	11 2.738	1.04	1.32	-1.000	1.489	-2	
62	0	1.031	0.308		3.8	+3			55
63	0	24 1	11	1.363	9522.0	984.0		PUMP SUCTION	
64	0	25	11 0.3081	4.421	0.4429	0.890	5.06035	-3	
65	0	0.3081	0.3081		3.8	+3			51
66	0	25 1	111	1.109	1.1183	+4	984.0	PUMP DISCHRG	
67	0	26	11 0.394	2.817	.334	-2.65	1.19	-3	
68	0	0.394	0.394		3.8	+3			58
69	0	26 1	11	7.581	1.1137	+4	984.0	R1H-IFR-E1F	2
70	0	27	11 0.4392	11.86	.06545	-5.10	2.899	-2	
71	0	0.3936	1.3934		3.8	+3			64
72	0	27 8	21 1 1	4.408	1.0700	+4	1100.0	REACTOR	
73	0	28	21 0.4997	6.30	0.00798	0.0	1.741	-2	
74	0	1.393	1.393		3.800	+3	3		
75	0	28 1	11	1.872	1.0230	+4	1162.6	END FITTING	
76	0	29	11 0.936	2.0	0.0792	0.0	5.705	-3	
77	0	1.393	0.317		3.8	+3	4		
78	0	29 3	11	9.49	1.0150	+4	1162.6	OULET FDR	
79	0	30	11 0.88	10.78	0.0768	+3.10	7.20	-3	
100	0	0.317	0.317		3.8	+3			

TABULATION OF INPUT DATA CARDS

CARD NUMBER	TOTAL ERRORS
101	0
102	0
103	0
104	0
105	0
106	0
107	0
108	0
109	0
110	0
111	0
112	0
113	0
114	0
115	0
116	0
117	0
118	0
119	0
120	0
121	0
122	0
123	0
124	0
125	0
126	0
127	0
128	0
129	0
130	0
131	0
132	0
133	0
134	0
135	0
136	0
137	0
138	0
139	0
140	0
141	0
142	0
143	0
144	0
145	0
146	0
147	0
148	0
149	0
150	0

```
                1.          2           3           4           5           6           7           8
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
30   1  11                1.670      9991 0    H      1162.6                    OUTLET HDR     6
      92 11     1.036       0.806       1 1485    0.0         0.0      -3
   0.2587    0.2494                  1.9    +3
      78 11     1.036       0.806       1.1485    0.0         0.0      -3
   0.2587    0.2494                  1.9    +3
92   1  11                .46390     9991 0                  1162.40
      93 11    .257692      1.801      .405034    .3331464    1.29     -3
   0.2494    0.3082                  1.9    +3
93   1  11                .99536     9966.0                  1162.6              PIPING
      31 11    .327164      3.051      .4563765   1.42685     .537619  -3
   0.3082    .536                    1.9    +3
78   1  11                1.46       9966.0                  1162.6              PIPING
      31 11    0 3008       4 85       0 438      1.76        2.264    -3
   0.2494    .536                    1.9    +3
31   1  11                2.85       9886.0                  1162.6              SG INLET HD
      32 11    2.738        1.04       1.32       1.00        6.23     -3
1.072        1.031                   3.8    +3
32   1  31   2   351.698             9854.0                  1128.0              SG U-TUBES     9
      33 31    21.031       1.639      0 0136     1.639       0.0
1.031        1.031                   3.8    +3
33   1  31   2   351.698             9854.0                  1100.0              SG U-TUBES     9
      34 31    21.031       1.639      0 0136     1.639       0.0
1.031        1.031                   3.8    +3
34   1  31   2   55 2.042            9635.0                  1077.0              SG HT          9
      35 31    21.031       1.982      0.0136     1.840       2.03     -4
1.031        1.031                   3.8    +3
35   1  31   2   55 2.042            9635.0                  1057.0              SG HT          9
      36 31    21.031       1.982      0.0136     1.840       2.03     -4
1.031        1.031                   3.8    +3
36   1  31   2   55 2.042            9635.0                  1041.0              SG HT          9
      37 31    21.031       1.982      0.0136     1.840       2.03     -4
1.031        1.031                   3.8    +3
37   1  31   2   55 2.042            9635.0                  1028.0              SG HT          9
      38 31    21.031       1.982      0.0136    -1.840       2.03     -4
1.031        1.031                   3.8    +3
38   1  31   2   55 2.042            9635.0                  1017.0              SG HT          9
      39 31    21.031       1.982      0.0136    -1.840       2.03     -4
1.031        1.031                   3.8    +3
39   1  31   2   55 2.042            9635.0                  1008.0              SG HT          9
      40 31    21.031       1.982      0.0136    -1.840       2.03     -4
1.031        1.031                   3.8    +3
40   1  31   2   55 .563             9525.0                  1003.0              PREHEATER HT 15
      41 31    21.031       .5462      0.0136    -.5462      0.0
1.031        1.031                   3.8    +3
41   1  31   2   55 .563             9525.0                  998.0               PREHEATER HT 15
      42 31    21.031       .5462      0.0136    -.5462      0.0
1.031        1.031                   3.8    +3
42   1  31   2   55 .563             9525.0                  993.0               PREHEATER HT 15
      43 31    21.031       .5462      0.0136    -.5462      0.0
1.031        1.031                   3.8    +3
```

TABULATION OF INPUT DATA CARDS

```
CARD  TOTAL
NUMBER ERRORS        1         2         3         4         5         6         7         8
          12345678901234567890123456789012345678901234567890123456789012345678901234567890

  151     0      43    1    31   2   55  563      9525.0          990.0          PREHEATER HT 15
  152     0           44    31   21 031       5462       0 0136   -.5462    0 0
  153     0         1 031     1 031                 3.8     +3
  154     0      44    1    31   2   55  563      9525.0          987.0          PREHEATER HT 15
  155     0           45    31   21.031       5462       0.0136   -.5462    0.0
  156     0         1.031     1.031                 3.8     +3
  157     0      45    1    31   2   55  563      9525.0          984.0          PREHEATER HT 15
  158     0           46    31   21 031       5462       0.0136   -.5462    0.0
  159     0         1 031     1.031                 3.8     +3
  160     0      46    1    11            2.85      9516.0          984.2          SG OUTLET HD
  161     0           47    11    2 738       1.04        1.32     -1.000    1 689   -2
  162     0         1.031     0.308                 3.8     +3                              57
  163     0      47    1    11            1.363     9522.0          984.0          PUMP SUCTION
  164     0           1    11       0.3081   4.421     0.6429    0.890     5.06035 -3
  165     0        0 3081     0.3081             3.8000  +3                              52
  166     0      55    1  2042    2       1 109  +19600.      H    1100.     H    SG FW
  167     1      95    1  2012            45.3      9900.           1162.7         PRESSURIZER
  168     2   *AUXVC/N
  169     2      1    1 3.0    +02222.2222  6.3405 -3 3.7    +1 6.1214 -3 2.7    -3 3.335  -1
  170     2           1.035   +4 1.4     -2 3.496  -1 6.37   +3             9.9995 +0 1.25   -2
  171     2           1.90    +2
  172     2      2    2 3.0    +02222.2222 2222.2222  2.0       3.55    +3 7.9375 -3 6.8072 -3
  173     2           1.83439-2 4.94    -1 8.41   +3              25.       8.0        4.4359694
  174     2           6.0     -3 1000
  175     2   *NKINS
  176     2           2.95    -4 1.165  -3 1.035  -3 2.25   -3 7.6    -4 1.98   -4 6.12   -4
  177     2           3.155   -2 1.218  -1 3.175  -1 1.389  +0 3.784  +0 1.0    -3 1.63   -2
  178     2           1.60    -2 3.57   -2 9.35   -2 1.395  -2 4.0    -4 5.0    -3 .05    +0
  179     2   *RPARM  110 1112035 2.5    -1 1.0    -5 1.0    -5 5.0    -5 2.0    -5 1.001
  180     2   *AFLUX/AUTO
  181     2   *ZPOWR  2.0325        +6    2    2         0.
  182     2           1.0       1.0
  183     2           0.0       0.0
  184     2           1.0       1.0
  185     2           0.0       0.0
  186     2   *CSTAT   0 0 1 1 2 2 1 2 2 2 2 2 0 2 0 0
  187     2   *TCONS    0.3  15.   15.          .3   .3  15.   15.   15.
  188     2   *REACT      10   10
  189     2           0.0       7.37      0.1       10.09
  190     2           200.0     4.80      100.0     8.56
  191     2           400.0     2.97      300.0     5.79
  192     2           600.      1.56      500.      3.34
  193     2           800.      0.51      600.      2.20
  194     2           924.      0.0       700.      1.11
  195     2           930.      -0.02     800.      0.07
  196     2           1000.     -0.27     807.02    0.0
  197     2           1200.     -0.82     900.      -0.93
  198     2           1300.     -1.3      1000.     -1.89
  199     2   *PLOTS D 02STSK
  200     2                     1.,-3.,2.,-5.,3.,-5,4.,-5.,5.,-5.,7.,-5.
```

TABULATION OF INPUT DATA CARDS

CARD NUMBER	TOTAL ERRORS	1 2 3 4 5 6 7 8 12345678901234567890123456789012345678901234567890123456789012345678901234567890
201	2	
202	2	11. ,13. ,14. ,16. ,24. ,1.124.
203	2	7.100.26.0.7.2.7.38.
		*END 100 0